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MOST HUMBLY DEDICATED TO HIS MAJESTY,
BY HIS MAJESTY'S MOST GRACIOUS PERMISSION,

A
TREATISE
ON
TOPOGRAPHY:

IN WHICH
THE SCIENCE AND PRACTICAL DETAIL
OF
Trigonometrical Surveying
ARE EXPLAINED:
Together with their Application to
SURVEYING IN GENERAL;
BESIDES VARIOUS OTHER SUBJECTS,
Including the Description and Use of the *Repeating Circle* and BORDA's *Reflecting Circle;* as well as Tables from which the Height of any Place may be ascertained with the Barometer, by the mere Subtraction of Two Numbers:

AND ALSO
A Translation of the celebrated Essay on *Military Reconnoitring, Descriptive* and *Military Memoirs*, written by COLONEL ALLENT, of the French Royal Engineers.

COMPILED AND PARTLY WRITTEN
BY
GENERAL DE MALORTIE,
Maréchal des Camps et Armées du Roi, Knight of the Royal Military Order of St. Louis and of the Decoration of the Lys, and Professor of Fortification and Artillery in the Royal Military Academy at Woolwich.
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A
TREATISE
ON
TOPOGRAPHY.

PART THE THIRD.

On the Triangles of the second order, or Secondary Triangles.—On the method of forming Triangles on the ground, and of resolving them by plane Trigonometry.—Important remarks.—Problems.—On the various manners of performing minor *Surveys, and transferring them to paper.—On some practical means used in Levelling.*

THE theory, relative to the triangles of the first order, has been explained in the first part of this Treatise. The reader, therefore, possesses all the elements requisite for determining the outlines of a Trigonometrical Map, and disposing the principal masses of the country which it is to represent; but it will not suffice to have thus erected the frame work of the edifice; all its parts must still be arranged in such a manner as to render it more easy to give it afterwards the form which it must have: such is the object which the secondary triangles are to accomplish.

The theory applied to the principal triangles is also applicable to those of the second order. The same method, the same operations, and strictly speaking, the same instruments may be used for both ;* and the only operations which secondary triangles do not require are, on the one hand, the determination of azimuths, as those which were obtained in forming the principal triangles are sufficient; and, on the other, the measure of any particular base, since such or such computed side of a principal triangle will furnish one at pleasure.

We shall not dwell any longer on the subject of secondary triangles ; and we only observe, that, as they do not indispensably require the same precision as those of the first order, *(See Part I. p.6.)* an error of a few seconds, in measuring the angles, is nothing in comparison with the advantage of dispatch in the operation ; wherefore the sextant may be recommended for common observations applicable to secondary triangles, unless they are made at the same time as those which relate to the principal triangles, and with the same instrument. Indeed, the sextant has the defect of requiring the parallelism of the mirrors to be verified at almost every station, and this cannot be done under a certain time. But, on the other side, the observer, who holds it in his hand, can handle it in almost the same space, and with nearly the same facility as a common telescope ; he may use it in a tree, in a window, on the top of a house, and even on horseback ; wherefore the observations can be made with as much ease as expedition.

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* The triangles of the second order are frequently formed at the same time as those of the first, the angles being taken with the same instrument.

On the method of forming Triangles on the ground, and of resolving them by plane Trigonometry.

We refer the reader to what has been said in the first part of this Treatise, (*p.* 90,) respecting the *spherical excess* of the three angles of a triangle, and shall now explain the method of forming triangles on the ground, and of resolving them by plane Trigonometry.

Let C, D, E, F, G, H, I, K, L, *pl. I. fig. I.* be remarkable objects, as towers, steeples, mills, &c. the respective positions of which we are to determine.

First, an elevated situation is to be chosen, as a tower, a steeple, &c. from which the greater number of those objects can be seen; we ought then to repair to all places where we may obtain a general knowledge of them, in order to make a rough sketch which will afterwards serve to indicate the measures to be taken in the course of the operation. The names of the objects C, D, E, *&c.* should be written upon this sketch, and notes be made of the most remarkable particulars by which they may afterwards be distinguished from each other, as, by this means, mistakes in their respect will be avoided. In short, it is proper, for greater certainty, to design the distance nearly at which we judge them to be, that we may not confound them with other objects which may have a resemblance to them, or be situated in their directions.

This being done, a base A B, chosen on a convenient spot, and as much as possible in a central position with respect to the objects C, D, E, &c. is to be carefully measured, as described in the first part of this Treatise. The instrument with which it is proposed to take the angles, suppose a Theodolite, is then to be transported to the extremity A of that base, and so disposed that its centre will exactly correspond with the point A, and the fixed index be directed along the line A B, to a signal placed at the point B; care should also be taken to render the instrument perfectly horizontal, according to the indications of the spirit levels which are generally attached to it. Next, the fixed index remaining in the direction A B, the moveable one is to be pointed successively to all the objects that are conveniently situated, and can be seen from the point A, as C, D, E, F, G, H, in order to measure the angles B A E, B A D, B A C, B A H, B A G, B A F, which the visual ray, directed from the point A upon each of these objects, makes with the base A B. After each observation, the measure of the angle should be written in a register, which ought to be headed with the name of the place where it is taken. The objects to which the moveable index is directed should also be entered in this register.

The observations to be made at the extremity A of the base being completed, the Theodolite is to be placed at the other extremity B, in the same manner as at A, and the angles A B C, A B D, A B E, A B F, A B G, A B H, made by the visual rays directed from this station to the objects C, D, E, &c. are to be measured. The distances of these objects to the points A and B, are then to be found by calculation from the triangles A E B, A D B, A C B, &c. in each of which there will evidently be known one side, which is the base A B, and the two adjacent angles.

With regard to the two objects K, L, which could not be taken from the extremities of A B, it will be necessary to remove to the points C, D, which have already been determined, and from which the objects can be conveniently perceived; then, considering C D as a base, the angles L C D, K C D, L D C, K D C, which the visual rays drawn from the extremities C and D to the objects L and K make with it, are to be measured; and the triangles C L D, and C K D, are then to be resolved; but, as the angles only are known, it will first be requisite to calculate the side C D, which is easily done by means of the triangle A C D, in which we know the angle C A D, the difference between the two angles C A B, D A B, and the sides A C, and A D, which are given by the preceding calculation.

Let I be one other object, which has not been taken neither from the extremities of the base A B, nor from those of C D. Here the side C L of the triangle C L D, the length of which has previously been determined, is to be taken for a base; and after having observed the two angles I C L, I L C, the other parts of the triangle may be readily found from having one side, and the two adjacent angles, given.

It is by such proceedings as these, that those points of a map which appear doubtful are verified, and new ones introduced. The secondary triangles are also formed in the same manner; for, if we suppose that the point *m*, inside of the principal triangle C L D, is to be taken, it is evident, that, by observing from C and D the angles *m* C D and *m* D C, we shall have the triangle C *m* D, in which we know the side C D, and the two observed angles.

This example has been limited to a small number of objects, in order to simplify both the explanation and the figure, as, without it, they would have become confused and embarrassing to beginners. But what has been said will doubtless be sufficient to show in what manner a survey may be extended at pleasure, by means of a series of triangles commencing at a measured base, and conveniently carried on according to the position of the objects to be taken, and the localities of the situation. We shall, therefore, only add, that, in extensive surveys which require great accuracy, the most certain method is to measure from one base to another by different series of triangles leading to the same two objects, and then to take the mean of the results.

Important Remarks.

1st. When two angles of a plane triangle are known, it will suffice, in theory, to subtract their sum from 180°, in order to obtain the third angle; but this method is not always sufficient in practical surveying; and when the map of a country is to be made with great accuracy, the three angles of each triangle should be measured whenever it can be done.

2nd. Should we be compelled to observe a very acute angle, we ought not only to measure it with great care, but also to consider the result as doubtful.

3rd. It is likewise essential not to employ in the calculation of distances any angle which is either very acute or very obtuse.

4th. At the same time that the angles formed by the objects which have not yet been surveyed, are measured, we should avail ourselves of all suitable stations, in order to connect with new triangles points already determined, especially if we consider them as doubtful; and by resolving these triangles, it will be seen whether the calculation assigns the same situations to those points as they were previously made to occupy.

For example; suppose the point I, *pl.* 1. *fig.* 1, had been determined by means of the triangle C I L, and that on account of the situation of this point being considered as doubtful, we wish to verify it from the station D, where we are placed in the course of the observations; if the two points I and D be conceived to be joined by the line I D, and the angle C D I to be measured, we shall have the triangle C I D, in which, besides this angle, there are known the side C D, previously determined, and the angle I C D equal to the sum of the two angles L C D, I C L, which have also been observed. Then the triangle C I D may be resolved, and it will be seen if this new calculation gives the same length for C I, as had been previously assigned to it.

5th. The reader has been informed, in the first part of this Treatise, page 5, that it is customary in Trignometrical surveys, to measure bases called *bases of verification;* by which it was meant, that the distance between two objects, which had been already determined by calculation, is actually measured; and if the two results are found to agree, it is a proof that the operations made before the base of verification was measured, are correct; but, if these results are sensibly different from each other, it ought to be concluded that some error has been committed, and the work must be revised.*

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* In proof of the great correctness of the English survey, which is now carrying on under the direction of Major Colby, of the Royal Engineers, we shall state the following particulars, extracted from Dr. Hutton's Mathematical Course, vol. iii. p. 120.

General Roy, who first measured the base on Hounslow Heath, measured another on the flat ground of Romney-marsh, in Kent, near the southern extremity of the first series of triangles, and at the distance of more than sixty miles from the first base. The length of this base of verification, as actually measured, compared with that resulting from the computation through the whole series of triangles, differed only by twenty-eight inches.

Colonel Mudge measured another base of verification on Salisbury Plain: its length was 36574,4 feet, or more than seven miles. The measurement did not differ more than *one inch* from the computation carried through the series of triangles, from Hounslow Heath to Sa-

6th. We should never leave a station before we have resolved all the triangles which can be calculated there, as, by delaying the work till another time, errors may be discovered which will oblige us to return to a place from which we may be very distant.

7th. Whenever it can be done, the base must be taken in the direction of two fixed and very visible objects; as, by this means, it will be more easy for us to follow it exactly in measuring it, than if we were guided by two signals which could only be seen with difficulty, or which the wind or other causes might derange. In order to ensure accuracy in this measurement, a sufficient number of persons should be employed and divided into several parties, independent from one another; which, after measuring the base separately, communicate to each other the results of their respective operations. If each party has found the same length, the measurement is undoubtedly exact; nay, it may be considered as such, if the differences of the several measures are very slight; it will be sufficient in this case, to take a mean of the results, which will still diminish the small error that has been committed; but, if the differences be great, the base must be measured again.

The following works will furnish the reader with excellent precepts relative to the measurement of bases which require great accuracy in the operation. " La Figure de la Terre, par Bouguer; Le Voyage Astronomique

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lisbury Plain,—a most remarkable proof of the accuracy with which all the angles, as well as the two bases, were measured!

The distance between Beachy-Head, in Sussex, and Dunnose, in the Isle of Wight, as deduced from a mean of four series of triangles, is 339397 feet, or more than 64¼ miles. The extremes of the four determinations do not differ more than 7 feet, which is less than 1⅓ inches in a mile. Instances of this kind frequently occur in the English survey."

et Géographique du père Boscovich: Méridienne de L'Observatoire de Paris, par Cassini: Mesure d'un arc du Méridien, par Delambre. An account of the measurement of a base on Hounslow Heath, in 1784, by General Roy. The account of the Trigonometrical survey of England and Wales, by Colonel Mudge.

Problems.

PROB. I.

As we were measuring with rods one side of a triangle, we met a sloping ground, and measured along the declivity, in order to avoid the inconvenience of holding the rods in a horizontal direction. Now, as the inclined line, thus measured, is greater, of course, than its corresponding horizontal line, it is required to reduce the length of the former to that of the latter.

SOLUTION.

Let A B, *fig.* 3, be the inclined line which has been measured, and A F a staff of the same length as the instrument B D, (suppose a Theodolite) which has been used for taking the angle of depression E D F = B A C, of the top of the staff below the horizontal line E D. If we suppose C D to be perpendicular to E D, it is evident, first, that the line A C, parallel to E D, will be the horizontal line corresponding to A B. Secondly, that the triangle A C B = D E F, will be a right angled triangle; we have, therefore, as Rad. : A B :: cos. B A C = cos. E D F : A C; that is, $AC = \frac{AB \times \cos. BAC}{\text{Rad.}}$

But, as the angle of depression E D F, and consequently its equal B A C, are almost always very small, it will generally be the most convenient to calculate the excess of A B above A C in the following manner: $A\,B - A\,C = AB\,(1 - \cos.\ E\,D\,F) = 2\,A\,B\,\sin.^2 \tfrac{1}{2}\,E\,D\,F$; that is, *the quantity to be subtracted from the length of the inclined line A B, in order to reduce it to its corresponding horizontal line A C, is equal to twice that length multiplied by the square of the sine of half the angle of depression.*

This last formula is employed for reducing the lengths of the rods used in measuring bases, to their corresponding horizontal lines; but this correction is seldom required in Geodesic operations applied to minor purposes.

PROB. II.

Suppose that it is required to determine the triangle A B C, *fig*. 4, the side A B, and the angle A B C, only being given; and that a wood, or some other obstacle situated in the direction A C, does not allow any of the other angles to be observed: suppose also, that, on account of a pond, or a morass, &c. the whole length of B C cannot be actually measured.

SOLUTION.

Measure on the side B C, or on that side produced, the greatest possible length C D, so that the object A may be seen from the point D; then, if the angle A B D be observed at B, and the angle A D B at D, one side and two angles will be known in the triangle A D B. Therefore, B D may be found by calculation; and, if the length C D be added to it, or subtracted from it, according as this length was measured on the side B C, or on its prolongation, the side B C will be obtained; but the angle A B C is known by hypothesis; the triangle A B C may therefore be resolved, since the two sides A B, B C, and the contained angle, are known.

Now, let us suppose that the length C D cannot be measured, neither upon the side B C, nor its prolongation; or, that B C cannot be sufficiently extended in that direction to allow the point A to be seen. In this case, a right line C E is to be measured in any direction, either to the right or left of the point C. Then, if we observe at B, the angles C B E, E B A, and at E, the angles A E B, and A E C, these angles, and the side A B which is known, will furnish sufficient data for computing the lines B E, B C, and then resolving the triangle A B C in the manner above stated; thus, the line B C will be connected with the preceding triangles, and may be used as a base in the series of operations.

PROB. III.

Let A B, *fig*. 5, be any known distance, at the extremities of which the necessary observations cannot be made for determining the right line C D, from which it is required to form a series of triangles connected with those by which A B has been found. Suppose also, that it is impossible to measure C D, either wholly or in part, or even any other line of which C or D is one of its extremities; wherefore, nothing more can be done than to observe the angles A C B, B C D, at the point C, and the angles C D A, and A D B, at the point D.

SOLUTION.

As the line C D cannot be measured, any length C *d* must be assumed for it, and whatever that length may be, it will not change the values of the angles taken at the points C and D. These angles remaining the same, the sides of the triangles which result from the assumed length of C D, will be proportional to the homologous sides of those which the true length of that line would give, since the former triangles are similar to the latter.

This being premised, if the angles A C B, B C D, are observed at the point C, and the angles C D A, A D B, at the point D, two angles and the side C *d*, the assumed length of C D, will be known in the triangle *a* C *d*, which is similar to the triangle A C D; therefore, the sides C *a* and *d a* may be calculated. And as two angles and the side C *d* are also known in the triangle *b d* C, the sides C *b* and *d b* may likewise be computed. Lastly, in the triangle *a d b* the two sides *d a*, *d b*, and the contained angle *a d b*, are known, from which *a b* will be found; we shall then have the true distances by making the following proportions, viz.

$$\text{As } ab : AB :: \left\{\begin{array}{l} Cd : CD \\ ac : AC \\ ad : AD \\ bc : BC \\ bd : BD \end{array}\right\} \text{The required lines.}$$

PROB. IV.

To find the position of a place from which three points, previously determined, can be seen; but such, that from these points the place cannot be perceived.

SOLUTION.

Let A, B, C, *fig.* 6, be the three points, the positions of which are given, so that all the parts of the triangle A B C are known; and let D be the point to be determined. It is required to find the distances B D, A D, and C D, by observing the angles m and n at the point D.

In the triangles A B D, B C D, which have the side B D common, we have $BD = \frac{AB \sin. x}{\sin. m.} = \frac{BC \sin. z}{\sin. (m+n)}$. But $z = 180° - n - y = 180° - n - (180° - B - x) = x + B - n$;

therefore, $\sin. z = \sin. x, \cos. (B - n) + \cos. x \sin. (B - n)$
$$= \frac{A\,B \sin. (m+n)}{B\,C \sin. m} \times \sin. x.$$

By dividing the last equation by the sin. x, we obtain
$$\cot. x = \frac{A\,B \sin. (m+n)}{B\,C \sin. m \sin. (B-n)} - \cot. (B - n) \text{ or,}$$
for the sake of greater convenience in the calculation,
$$\cot. x = \cot. (B - n) \left(\frac{\sin C \sin. (m+n)}{\sin. B\,A\,C \sin. m \cos. (B-n)} - 1 \right);$$
from this equation we shall have the segment x of the angle B A C; consequently, the other segment C A D, will be known, and the resolution of the triangles A B D, A C D, will give the required distances.

This solution possesses the advantage, that the equation, from which it is obtained, holds good in all cases, as appears from the following observations.

In fact, if we had $B < n$, cot. $(B - n)$ would be negative, which is the only change in the equation. Now, supposing the point D to be within the triangle A B C, we shall have $(m + n) > 180°$, and then the sin. $(m + n)$ will likewise be negative. Besides, although one of the angles A, B, C, may be obtuse, yet the segment of one of the acute angles is to be sought, in order to avoid any embarrassment and uncertainty respecting the species of the angle x.

If B were equal to *zero*, which happens when the three points A, B, C, are in the same right line, (the point A must then be supposed at y, and the angle x changes into B y D), we should have, $\cot. x = \cot. n \left(1 - \frac{A\,B \sin. (m+n)}{B\,C \sin. m \cos. n}\right) = \frac{A\,C \cot. n - A\,B \cot. m}{B\,C}$. Finally, when B is equal to n, the problem is indeterminate, as in this case, cot. $(B - n)$ is infinite, and the point D may have numberless positions, all of which will satisfy the conditions of the question. The following construction, if used, will make it evident.

Should we not wish to determine the distances A D, B D, and C D, but only the proper position of the point D in the map, it will be more readily found by this construction.

If a circle be supposed to pass through the points A, B, D, we shall have $\frac{1}{2}$ A B = sin. m; and as this sine is proportional to the radius of the circle, it will be easy to find the radius by dividing $\frac{1}{2}$ A B by the sin. m, taken from the tables. In the same manner, $\frac{AC}{2 \sin. n}$ will be the radius of the circle which would pass through the points A, C, D. Therefore, if these two circles be described with their respective radius, such as found by the calculation, they will intersect each other in the point A, and also in another point, which will determine the position of the point D on the map.

PROB. V.

From the top of an eminence, the height of which is given, to determine the horizontal distance between two objects situated below.

SOLUTION.

Let R, *fig.* 7, be the elevated point, the height of which above the common horizontal plane of the objects A, P, is equal to R E; the distance A P may be determined from R, in the following manner:—

Take the angle A R P, and the angles of depression, or the complements of P R E, and A R E; the angle A R P is then to be reduced to A E P,* and the two others, with the side R E, will serve to calculate A E and P E. Thus we shall have all the requisite data for finding the distance A P.

---

* Cagnoli gives the following formula for making this reduction, independently of the two other angles.

In order to give an idea of the practical utility of this problem, it will be sufficient to observe, that, as it is easy to measure an altitude with great accuracy by the barometer, we may determine, from a projecting part of a steep mountain, the positions of the towns and other objects situated in the valleys which it overlooks, without the necessity of measuring a base.

In the triangles A P R, A P E, which have a common side A P, we have

$$AP^2 = AR^2 + PR^2 - 2AR \times PR.\cos.ARP$$
$$= AE^2 + PE^2 - 2AE \times PE.\cos.AEP,$$

from the last equation we obtain

$$\cos.AEP = \frac{AR \times PR.\cos.ARP - RE^2}{AE \times PE},$$ which gives

$$\cos.AEP = \frac{\cos.ARP - \sin.RAE.\sin.RPE}{\cos.RAE\cos.RPE},$$ or for increasing the facility of the numerical calculation, $\cos.AEP = \text{tang}.RAE\ \text{tang}\,RPE\left(\frac{\cos.ARP}{\sin.RAE\sin.RPE} - 1\right)$ From the former of these two formulæ, which is the easier to enunciate, Cagnoli deduced the following rule for reducing the angle having its vertex out of the plane of reduction. *The co-sine of the reduced angle is equal to the co-sine of the observed angle, minus the rectangle of the sines of the angles of elevation, the remainder being divided by the rectangle of the co-sines of the same angles.*

The following expression, which Delambre has given, is more convenient for calculation than the preceding: $\sin.\frac{1}{2}AEP =$

$$\sqrt{\frac{\sin.\frac{1}{2}(ARP+RAE-RPE)\sin.\frac{1}{2}(ARP+RPE-RAE)}{\cos.RAE.\cos.RPE.}}.$$

On the various Manners of performing Minor *Surveys, and transferring them to Paper.*

All surveys do not indispensably require the great accuracy which the Geodesic operations, already explained, are intended to afford, as in many circumstances a smaller degree of precision will sufficiently answer the purpose; for instance, if we are to survey an estate, a lordship, or any other moderate extent of a country; to take the plan of a camp, a position, a town, a fortification, &c. or if it be required to survey the country along a road, or the banks of a river, to fill up a map, the principal points of which have been previously determined, we may, in these cases, undoubtedly dispense with the greater number of the above-mentioned Geodesic operations; nay, with any kind of calculation, at least in most circumstances. All those minor surveys will be treated of in this part of the work, but it is requisite that we should premise a description of the Implements employed for Surveying, and explain the methods of making Scales, tracing a right Line on the ground between two objects, and measuring it with a Chain, or with Rods.

A Description of the IMPLEMENTS *employed for Surveying.*

BANDROLS. A Bandrol, *pl.* 2, *fig.* 8, is a round pole, about 9 feet long, and 1¼ inch in diameter at its lower extremity; it is tapered towards the top, where a white flag, about 18 inches long and 12 inches wide, is fastened;

and it is shod at foot with a pointed cap of iron, that it may be easily fixed into the ground. Bandrols are used in tracing long lines, as they are seen from a greater distance than staves.

STAVES. The height of a staff, *fig*. 9. is from four to five feet; staves are made square and tapered towards the top, which is split in the middle, in order to receive a small square piece of white paper, which renders them more conspicuous: each face of a staff is about ¾ of an inch broad at bottom, and ½ an inch at top; and the lower extremity is shod with a pointed ferrule of iron, for the same reason as Bandrols. Staves serve for tracing a line which is of no great length.

PINS, OR ARROWS. Pins, or Arrows, *fig*. 10, are made of strong iron wire, about 15 inches long, and $\frac{3}{10}$ of an inch in diameter; they are pointed at one end, and the other is bent in the shape of a ring, to which a small piece of white or red cloth is fastened, that they may be better seen. Arrows are used in measuring a line with a chain, as will be explained.

A CHAIN, *fig*. 11, serves particularly for measuring long lines; it is composed of several pieces of strong iron wire forming as many links, one foot long,* including the small rings which join them together. The chain is terminated at each end by a larger ring, which serves for taking hold of it, and for stretching it with greater facility; and, in order that the odd links may be more quickly counted off, a brass plate is fastened to every tenth link.

A ROD, such as is used for measuring distances, is a kind of ruler, generally 10 feet long, and one inch and a quarter square, the ends of which are shod with brass or iron ferrules. It is divided into feet, and the first foot at each end is divided into inches. Rods are usually painted black, and the divisions are marked in white on both sides, with the numbers 1, 2, 3, &c. but in a contrary direction.

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* In land-surveying, a Gunter's chain is used; it contains 66 feet, or 4 poles, and is divided into 100 links, each 7.92 inches long, including the rings betwixt them.

MEASURING TAPES have various lengths. They are divided into feet, which are marked with the numbers 1, 2, 3, &c. and the first foot at each end is divided into inches.

On the methods of making Scales.

Scales serve for constructing maps in an assumed ratio with a determinate extent of ground: for instance, it is said that a scale is one inch for 500 yards, for a mile, &c. when such division of it as is equal to one inch, is the assumed length for a distance of 500 yards, one mile, &c. on the ground.

Diagonal scales are very convenient for transferring a minor survey to paper. They are constructed as follows:

Let it be required to make a scale of half an inch for 100 fathoms, the smallest division being one fathom.

Draw a right line A B, *fig.* 12, on which set off half an inch any number of times. At the extremities A and C of the first division, erect the indefinite perpendiculars A E, C D, and set off on each of them ten equal parts of any length. Then connect the opposite divisions by lines which will be parallel to A C. Lastly, divide A C and E D each into ten equal parts; and, after drawing transversal or diagonal lines through the points of division, as the figure shows, the scale will be completed.

For greater conveniency in taking dimensions, number the divisions along A C and C D, as is shown by the figure. Then, if you want the length of 30 fathoms, for instance, open the compasses from C to 30: and should 37 fathoms be required, follow the diagonal line drawn to 30, till you come to the point *c* opposite the division numbered 7 along C D, and extend the compasses, in the direction *c* 7, from *c* to the perpendicular C D; any other dimension which does not exceed 100 fathoms, is to be taken in the same manner.

When it is proposed to construct a figure similar to another, and to make a scale for it which bears a proportion, expressed in numbers, to the scale of the latter figure, this operation may evidently be performed with the greatest ease; since it will suffice to multiply or divide by 2, 3, &c. the length of any division of the given scale, according as the scale required is to be greater or smaller. But, if the surfaces of two similar figures are to be in a given ratio, the terms of which are not perfect squares, the required scale must be found, in this case, by a particular method, such as the following:

Draw a right line A E, *fig.* 13, on which set off A K and K E which are to each other in the given ratio. Bisect A E, and from the point of bisection as centre, with half A E as a radius, describe a semi-circumference; erect at K the perpendicular K D to A E, and draw the chords A D and D E. Then set off on A D, after producing it, if necessary, the scale A B of the given figure, and if B C be drawn, from the extremity B, in a direction parallel to the chord D E, it will give the length of the required scale.

The same operation may also be performed *instrumentally* by means of the *sector*, the use of which is generally known.

To trace a Right Line on the ground, between two objects.

Unless the distance from one point to another be small, it is proper, in order to measure it with greater accuracy, to trace a line between those points in the following manner:

Let it be required to trace a right line on the ground between two points A and B, *fig* 14.

Fix a staff at A, (or a Bandrol, should the distance A B require it,) and another staff at B. Then place successively several other staves *c*, *f*, between A and B, in such a manner, that your eye being as close as possible to the staff A, each intermediate staff as placed may appear but one with the staff B.

Whenever staves (or bandrols) are used, either for tracing a line on the ground, as has been explained, or for marking any point, they must be vertical, which may be easily ascertained as follows:

Suspend a plumb-line along two sides of each staff as it is planted, and if it hang close to them, the staff is vertical; if not, the position of the latter must be rectified.

To measure a Right Line A B *on the ground*, fig. 14.

WITH A CHAIN. The chain is used by two men, one of whom is called the *leader*, and the other the *follower*. The leader is supplied with a certain number of arrows, commonly with ten, when the length of the line to be measured requires so many; and after stretching the chain in the direction A B, while the follower keeps one end of it close to A, he thrusts an arrow into the ground at the point where the chain terminates; then he stretches it again from this point towards B, and fixes another arrow in the same manner as before, and so on, till the whole line is measured.

Should it happen that the leader deviates, in stretching the chain, from the direction A B, the follower must warn and rectify him.

It is to be observed, that, as the follower advances, he must take up the arrows which the leader has left; wherefore they serve, not only for showing the successive points from which the chain is to be stretched, but also for counting off the number of chains which have been measured, since this number is equal to that of the arrows.*

When no arrow remains to the leader, and the whole line is not yet measured, he ought to wait for those which the follower has taken up; and a memorandum must be carefully kept of the number of times they have been thus exchanged. It is proper, likewise, that the leader should count off the arrows as the follower returns them, in order to ascertain that their number is right.

Care must be taken, when measuring with a chain, that it should lie horizontally, in a proper direction, and be well stretched; and also, that none of the links should be bent, nor any of the small rings which join them together entangled. The leader and the follower are commonly supplied with a piquet, 3 feet long, which is shod with a pointed cap of iron, and run through by a wooden pin, 6 or 7 inches from its foot. These piquets being passed through the large rings at both ends of the chain, the wooden pin keeps it above the ground,† whilst the

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* Any other account of the number of chains measured may also be kept as an additional precaution. For instance, the leader and the follower may put a small stone in their pockets for every chain, or make a knot in a string fastened to one of their button-holes.

† It is here supposed that the ground is nearly level; wherefore it will suffice that the chain should be raised above the small irregu-

line of chords,* the angle $c\,a\,b$, equal to the angle C A B; and at b, the angle $c\,b\,a$, equal to C B A. The sides $a\,c$ and $b\,c$ of these angles being made sufficiently long to meet each other at c, this point will give the position of the object C. Determine in the same manner the positions of the objects D, E, F, G, and H.

Conceive the points c and d to be connected by a line, and, after describing on this line the angles $k\,c\,d$, $l\,c\,d$, $k\,d\,c$, $l\,d\,c$, respectively equal to the angles K C D, L C D, &c. place the objects K, L, at k and l, where the sides of those angles meet.

Lastly, describe on $c\,l$ the angles $i\,c\,l$ and $i\,l\,c$, respectively equal to I C L, and I L C, and the intersection i of the sides $c\,i$ and $l\,i$, will be the position of the object I.

This method of transferring a minor survey to paper will not afford as much accuracy as the former; but the degree of precision obtained from it will suffice in most of the circumstances in which such surveys are carried on.

It is customary to delineate the four cardinal points in a map, and the indication of them may be referred to any line. However, the best method is to refer it to the first base; for this purpose, measure the angle which the magnetic needle makes with this base on the ground,† and take into the account the variation of the needle in such year and such place. Then, after having thus corrected that angle, describe it on the map by drawing to the base a pencil line, which will indicate *North*. Now, if this line, or any other, parallel to it, which may be drawn in the most convenient part of the paper, be cut by a perpendicular extending on both sides; the cross thus formed will show the four cardinal points.

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* The use of the protractor and line of chords is so generally known, that we think it useless to explain it in this place.

† The use of the *compass*, for taking angles, will be hereafter explained.

Agreeable to custom, the northern part of a map should occupy the top of it.

General Description of the Plane-Table.

Of all the instruments that may be used in surveying the details of a country, there is none more useful nor more expeditious than the Plane-table. This instrument, *fig.* 15, is composed of a small square table, of greater or less extent, moving in all directions on a support to which a stand with three legs is adapted. The construction of this support should be such that a slow and gentle rotary motion can be given to the table, without deranging it from the horizontal position which it ought indispensably to preserve during the observations; and this position of the table is ascertained by means of a *spirit level,* successively placed upon two of its sides that are perpendicular to each other.

In the direction of two opposite sides of the table are placed outwardly two rollers, the axis of which is supported by two pieces of brass, or iron, and carries a toothed pinion at one of its ends; these rollers serve gradually to stretch and to roll up a piece of paper which is laid on the table, to trace the operations upon; and, that it may not be damaged during the work or soon after, it should first be pasted or glued upon a piece of muslin, or fine cloth. It is proper, likewise, in order to preserve the eyes from too vivid a reflection of the light, which the whiteness of the paper produces when exposed to the sun, to cover with a green paper all the parts of the table upon which the work is not immediately carrying on.

In taking angles with the Plane-table, a brass ruler, *fig.* 16, is used, at the extremities of which two perpendicular sights *a*, *b*, are fixed; the middle of the opening of each sight is in the same vertical plane with one of the edges of the ruler, and forms a line with it, which is called the *line of collimation*. The visual rays are directed through the sights from the points of station to any object, and the ruler serves for drawing right lines upon the paper, which correspond to those rays.

This kind of ruler is called an *index*, and is very common, wherefore we have noticed it. However, as it is only proper for small distances, and does not suit for directing the sights to objects that are much either above or below the horizontal plane of the station, indexes, which carry a telescope supported in the middle by a small brass stem fixed to the ruler, should be preferred. The telescope and the ruler being thus insulated from each other, the tube of the telescope may be inclined at pleasure for pointing to objects above or below the horizontal plane of the station, and the line of collimation represents precisely the orthogonal projection of the visual rays.

If it happen that the wires of the telescope present a *parallax*, in which case their image is less distinct than that of the objects,* it will be necessary to increase or diminish the distance between the wires and the object-glass, which latter is generally fixed to a small moveable cylindrical piece joined to the body of the telescope. The optic axis must then be rendered parallel to the plane of the table, by means of a *proof telescope*, as already explained in the description of the Repeating Circle, vol. i, p. 21.

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* This circumstance generally happens from the wires being not placed exactly in the focus of the telescope; and it is also known to subsist when, by removing the eye farther from the optic axis, the image of the object changes its place.

It is important that each point of station on the ground should agree precisely with that which represents it upon the paper on the table; and, in order to dispose the instrument conformably to this principle, compasses are used, the legs of which are curved and of sufficient length to reach nearly to the centre of the table. At the extremity of the lower leg a plumb line is suspended, which, the end of the upper leg resting upon the point marked on the paper, indicates the direction of the vertical line passing through this point, and consequently shows when the Plane-table is properly placed.

Otherwise. Suppose it were required to make the point of station A, on the ground, *fig.* 15, agree with the point *a*, which represents it upon the paper.

Place across the table, either parallel to one of its edges or very nearly so, a pack-thread, passing over the point *a*, and of such a length that its two ends, to each of which a plumb is attached, may nearly reach to the surface of the ground. Then measure the distance *a b* or *ac* from the point *a* to one of the edges of the table, and lay this distance down horizontally on the ground, between the two plumbs, on the same side of the point *a*, as it was measured on the table. It will thus be seen in what way the position of the instrument is to be changed, and after a few trials the two points A and *a* will correspond to each other.

As the plane-table is much used on the Continent in minor surveys, different persons have lately sought for means of improving it. We cannot, however, enter into details relative to the improvements that have been made in this instrument, as our object is not so much operation will be performed with greater ease and expetion by the following method; provided, however, the desirable points of station are accessible.

SECOND METHOD.

To take a plan, with the Plane-table, of the open ground A B C D E F, *fig.* 19, the principal surrounding points A, B, C, &c. of which are accessible, and can be seen from each other. It is supposed also, that the boundaries of this ground are rectilinear.

Measure the distance D E between any two of the principal surrounding points which are conveniently situated for the operations you are about to carry on, and plant staves at A, B, C, D, and F. Dispose the Plane-table horizontally at E, nearly in the direction of the ground to be surveyed, as has been explained, and make the point *e*, *fig.* 20, which you may take at pleasure on the paper, agree with that point. Then place the index in the direction E D, and after drawing *e d* in the plan, set off on this line, from the scale, the corresponding length of D E; from the point of station E, draw also the line *e f*, answering to E F, and indefinitely prolonged.

These preliminary operations being performed, plant a staff at E, and remove the Plane-table to F. Then, in order to rectify it, lay the index on *f e*, and turn the table on its support, till the staff E is seen through the sights. This done, fix a needle at *d*, and, after applying the index against it, turn the latter round, till you perceive the staff D. The index, in this situation, will meet the indefinite line *e f* in a point *f* corresponding with the point F on the ground; wherefore, if *e f* be cut at that point with a pencil-stroke, its length will be thus determined without measuring E F; from *f*, draw the line *f a*, in the direction of F A. Then fix a staff at F, and remove the Plane-table to A.

The Plane-table being properly disposed at A, and rectified by means of the direction A F and its corresponding line *a f* in the plan, lay the index, as before, against the needle fixed at *d*, and turn it round, till you see the staff D; then cut *f a* at the point *a* where the index meets it, and from the same point draw *a b*, in the direction of A B.

Now fix a staff at B, and after removing the plane-table to C, proceed at this point as you did at A and B. The outlines of the plan will thus be completely described, without measuring any other distance but D E; and with respect to the methods of filling them up, by taking the particulars of the ground, they will be explained in the subsequent pages.

It is of material importance, when we are surveying with a Plane-table, to ascertain the accuracy of the work as frequently as possible, if this cannot be done at every station; and the Plane-table affords the means of performing that operation with the greatest ease; for instance, suppose the instrument to be placed at the station C, and that after determining the point *c*, we lay the index in the direction of this point, and of any other point *a* which was previously taken; the staff A, in this case, should undoubtedly appear through the sights, since it lies in the direction C A, which corresponds to *c a;* and if it be not seen, the work is somewhere wrong. As a further precaution, we may also, when closing the work, avail ourselves of the method of proving it explained in page 30.

The Reader has seen that, in the two methods already explained, a polygon was first traced round the ground to be surveyed, by planting staves at the principal surrounding points; then the angles of that polygon were taken, and the lengths of its sides determined. We shall now exhibit another method, which is particularly useful when the surrounding points are not accessible.

THIRD METHOD.

To take a plan, with the Plane-table, of the ground A B C D E F G, *fig.* 21, the principal surrounding points B, C, D, F, G, of which are inaccessible; wherefore the table can only be placed at A and E. It is supposed, besides, that the boundaries of that ground are rectilineal, and that the distance A E can be measured.

Dispose the plane-table at A, as in the preceding methods, and take also a point *a* at pleasure on the paper, *fig.* 22, to represent the point of station A on the ground; make these two points coincide with each other, and draw the line *a e* in the direction of A E; then, turn the index successively round the needle fixed at *a*, till you perceive the objects B, C, D, F, G, through the sights, and draw the lines *a b*, *a c*, &c. in the direction of the visual rays with which they respectively correspond; taking care to ascertain, after drawing each of these lines, that *a e* still coincides with A E; if it does not, it must be brought again into that direction, and the line be drawn anew.

This done, measure A E, and set off on *a e* its corresponding length from the scale; then remove the table to E, where it is to be disposed as it was at A, the point *e* coinciding with E, and the line *e a* with E A; Lastly, draw from E the visual rays E B, E C, &c. and the intersections of the lines *e b*, *e c*, &c, which represent these rays in the plan, with the lines *a b*, *a c*, &c. previously drawn from the station A, will give the positions of the objects, B, C, &c.

Without altering the position of the table, direct a visual ray E I to a staff planted at any point I, and draw the indefinite line *e i* corresponding with E I; place a staff at E, and after removing the plane-table to I, rectify it by making *e i* and E I coincide again with each other; then, fix a needle at any of the points *b*, *c*, *d*, at the point *b* for instance, and turn the index round it till you see the object B through the sights; cut *e i* at the point *i*, where the index meets it, and this point will thus be determined in a manner analogous to the *second method*. Now, if the survey be right, and the index successively placed in the directions *ic*, *id*, *if*, &c. the objects C, D, F, &c. will appear through the sights.

Had a visual ray E H been previously directed from E to the object H, and its corresponding line *e h* indefinitely drawn, the position of this object in the plan might evidently be determined from the station I, the table remaining rectified, by turning the index round the point *i* till the object H is seen through the sights, and then cutting *e h* at *h*, where the index meets it.

By applying the *third method* of surveying with the plane-table, to the determination of the fundamental points of an extensive country, this operation could be performed with great ease and expedition, as no calcuation would be required; in fact, the objects C, D, E, F, G, H, *pl.* I. *fig.* 1, might, first, be taken from the extremities A and B of the base A B, conformably to that method; as well as the objects K, L, from C and D, the table being successively removed to each of these points, and rectified by means of the direction C D and its corresponding line in the plan. The object I might also be determined from C and L by the same method, and the survey be extended at pleasure in a similar manner; but, without specifying the defects of the

Plane-table, with regard to surveys of this kind, we shall say, in a general way, that the accuracy it gives is not adequate to that which is obtained from the instruments usually employed for the geometrical determination of the principal points of a map which comprehends a vast extent of territory, and that its great utility is limited to minor surveys.

Observations.—It is material, when the *third method* of surveying with the Plane-table is used, that not only the objects pointed to from the first station should be carefully observed, but also that particular part of them to which the index is directed; as, without it, mistakes might be made respecting the proper direction of the visual rays to be drawn to the same part from the second station.

Whenever the position of an object is to be determined by the intersection of two visual rays drawn to it, as in *second* and *third method* for instance, the angle which they form should not be very acute nor very obtuse, as, in both cases, the intersecting point of the lines, which represent those rays in the plan, will be doubtful, as well as the position of the object; however, as that inconvenience is sometimes unavoidable, it is necessary, in such circumstances, that more than two visual rays should be directed to the object, in order that its position in the plan may be regulated by the intersection of more than two lines. It is proper to take this precaution, likewise, when a survey is to be transferred to paper by one of the methods explained in pages 23 & 24.

As the table is disposed horizontally at every station, all the lines drawn on the paper are horizontal, and the plan only represents the horizontal projection of the sloping parts of the ground; it is therefore necessary, in measuring distances, that the chain should be stretched, or the rods held, as horizontally as possible.

Description and Use of the Declinatoire.

It is generally known that a magnetic needle, in a state of equilibrium on a pivot, always points to the north pole, and this property of the magnetic needle has suggested the idea of an instrument which is frequently used for rectifying the Plane-table.* The French call it a *Declinatoire*.

A Declinatoire is a small rectangular box *g*, such as represented in *pl.* 3, *fig.* 18, the breadth of which is about one half of its length; it contains a magnetic needle resting in a state of equilibrium on a pivot generally made of steel, although agate seems to be preferable; this pivot stands perpendicular to the bottom of the box, at the centre of it; in such a manner, that, when the box is laid horizontally, and both ends of the needle respectively correspond with a point or a fine line placed in the middle of each of the shorter sides of the instrument, its longer sides are parallel to the needle, and give, therefore, the direction of the magnetic meridian; the needle of the Declinatoire is not surrounded by a circle of metal divided into degrees as that of a surveying compass, but only indicates north and south.

The use of the Declinatoire, for rectifying the Plane-table, undoubtedly enables us to survey with greater ease and expedition than the method of rectifying it previously explained, and such advantage is very important in many circumstances: but it ought not to be dissembled that, in point of precision, the Declinatoire is not without defects; first, although the great distance of the north pole, in our latitude, allows us to regard without sensible error the positions of the needle, at the different points of the ground to be surveyed, as parallel to each other, yet this supposition is not strictly true, since the magnetic meridians are converging to each other towards the pole. Secondly, the declination of the needle frequently varies at different places, and sometimes on the same spot, according to the hour. Lastly, the proximity of ferruginous matters will also affect the direction of the needle; without speaking of the difficulty which it occasionally has in becoming steady, on account of its being agitated by the wind.

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* It is scarcely requisite to observe that, after rectifying the plane either by means of the Declinatoire or by the method before explained, it ought to be steadily fixed, as without it the weight and motion of the index, or some other causes, might [illegible] the plane from its position.

That the reader may more easily compare the two methods of rectifying the Plane-table above cited, we shall now apply the use of the Declinatoire to the solution of the following problem, which was previously resolved without employing it. (See the *first method*, page 28.)

Let it be required to take, with the Plane-table, a plan of the wood A B C D E F, *pl.* 3, *fig.* 17, the skirts of which form straight lines, or very nearly so, &c.

Dispose the Plane-table at the first station A, *fig.* 17, as in the *first method*, and make also any point *a*, *fig.* 18, correspond with the point A of the ground which it represents; then, the table being fixed, lay the Declinatoire on any convenient part of the paper, and turn it till the extremities of the needle exactly correspond with the points or thin lines traced in the middle of its shorter sides; draw a pencil line along one of the longer sides, and this line will give the direction of the magnetic meridian: draw also *a b* and *a f*, as has been explained in page 29, and, after measuring A B, set off from *a* to *b* its corresponding length, taken from the scale of the required plan.

This done, remove the Plane-table to C, without making any station at B, and dispose it horizontally; then place the Declinatoire as it was at A, that is to say, lay one of its longer sides precisely on the pencil line which was drawn at this station in order to represent the direction of the magnetic meridian; and turn the table, until the needle corresponds with the points or thin lines before-mentioned. The table being thus rectified, turn the index round a needle fixed at *b*, till you perceive the object B through the sides; and draw the line *c b*, the direction of which shall be exactly the same, as if this line had been drawn from B;* measure C B, and, after setting off its corresponding length from *b* to *c*, draw *c d*, which is also to be made equal to the number of measures found in C D; the table being next removed to E, and rectified as has been explained, fix a needle at *d*, and turn the index round it till the object D appears through the sights. Lastly, if the corresponding length of E D be set off from *d* to *e*, and the line *e f* drawn, the outline of the plan will be completed, and the two stations B and D avoided.

It has hereto been supposed that the ground to be

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[*] The truth of this assertion is evident; for, let us suppose a station to have taken place at B, in order to draw *bc*, and that after determining the point *c*, it has been made to correspond with C, and the line *cd* to C D; the direction of the table, in this case, will be parallel to that which it had at B; then reciprocally, when the table is rectified at C, and thus placed in a direction parallel to that which it would have had at B, had a station taken place at this point, the line *c b*, drawn from the station C, exactly corresponds with C B, and is but one with *b c*.

surveyed was not connected with any other previously taken; wherefore the point *a*, *fig.* 18, which represents the first station A, *fig.* 17, might be chosen at pleasure; and also, that the boundaries A B, BC, &c. of that ground formed straight lines; now, we shall explain the method of proceeding when the required plan is connected with points already determined, and the boundaries do not form straight lines.

Let A and H; fig. 23, be the extremities of one side of a secondary triangle, and respectively represented on the table by the points a *and* h, *fig.* 24*; it is required to take a plan of the accessible ground A B C D E, the boundaries of which are not rectilineal, and to rectify the table with respect to the given side A H.*

Plant staves, or bandrols, at the principal points A, B, C, D, E, of the ground, so as to trace such polygon as the dotted straight lines A B, BC, C D, &c. represent; and dispose the Plane-table horizontally at A, the points A and *a* corresponding exactly with each other; then, lay the index on the line *a h*, and turn the table until this line precisely coincides with the side A H; the table will thus be rectified with respect to that side, and should you propose to use the Declinatoire for rectifying it at the other stations, the direction of the magnetic meridian must be traced, (*see page* 38) unless it is already represented on the paper.

From the same station A draw the line *a b*, the direction of which will be found, as usual, by turning the index round a needle fixed at *a*, till you perceive the staff B through the sights, and, after measuring A B, set off from *a* to *b* its corresponding length taken from the scale; likewise, measure the partial distances A *x*, *x y*, *y z*, between the perpendiculars *x x'*, *y y'*, *z z'*, let fall from the most convenient points of the boundaries to

A B*, as well as the lengths of those perpendiculars and transfer to the plan, both the distances and perpendiculars, as *a b* was transferred; that is, with their corresponding dimensions taken also from the scale; now, if the points *a*, *b*, and the ends x', y', z' of the perpendiculars be connected by one or several lines, according to the figure of the boundaries, the outline of the ground which answers to A B will be described. It is undoubtedly useless that we should dwell any longer upon this subject, as the explanations already given will enable the reader to conceive easily in what manner the remaining part of the survey is to be carried on, in order to complete the outline of the plan; and we shall only observe, that it is immaterial whether the polygon and perpendiculars are traced inside or outside of the boundaries, since the outline will be the same in both cases, as a mere inspection of the *figs.* 23 and 24 will show; wherefore this method is applicable to all kinds of grounds, such as woods, marshes, morasses, &c. provided their contour is accessible. The periphery of a town or a village, &c. may also be taken by the same method; as well as the windings of a road, the course of a river, and the sinuosities formed by fields, gardens, hedges, &c. since it will suffice to draw straight lines along the sides, and to let fall perpendiculars to these lines from all the points where it may be deemed requisite.

The required number of the perpendiculars of which we have been speaking, depends, as well as their positions, on the configuration of the boundaries, and it should be so much greater, as the ground forms more windings and turnings. It is customary to direct them to the principal angular points, but intermediary ones may also be used whenever it is thought that a more accurate delineation of the boundaries will be obtained by that means. The reader will find, in another Section of this work, some easy and expeditious methods of letting fall those perpendiculars; besides, their direction may be very nearly determined by the eye alone, where they are very short; and should the points x', y' z', lie at a great distance from A B, this line may be used as a base, in order to take those points from A and B with the Plane-table, according to the *3d method*, page 34.

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* If these distances are accurately measured, their sum will evidently be equal to the length of A B.

We shall now give the solutions of two other important problems, which will be found very useful in taking the details of a country, after the principal points have been determined.

PROBLEM I.

The principal points A, B, C, D, *&c. of the ground represented by fig.* 25, *being transferred from a map to the paper of the table, or determined upon it by actual surveying, it is required to fix the position of any point* G *within that ground, supposing that two of the principal points, at least, can be seen from* G, *and that the direction of the magnetic meridian is given on the paper.*

Let B and C be the two points which are seen from G; if the table be rectified at G, by means of the Declinatoire, in the manner explained in page 39, and the index successively laid in the direction *b* B and *c* C, the intersection of the lines *b* G and *c* G, drawn in those directions, will give the position *g*, of the point G, on the table.

Should not the direction of the magnetic meridian be given, it must be first traced as follows:—Dispose the table horizontally at any of the principal points A, B, C, &c. at B for instance, and make this point correspond with the point *b*, which represents it on the paper; then, the index being laid on *b c*, and the table turned till the object C appears through the sights, place the Declinatoire on the paper, and turn it, &c. as has been said in page 38.

The above method of taking intermediary points is as simple as convenient; wherefore, it is very frequently used; however, the reader has been made aware of the defects of the Declinatoire in point of precision, and, should greater accuracy be wished for than that which it generally gives, the following method may be employed.

PROBLEM II.

Three points A, B, C, *(fig. 26,) being given, and represented on the table by* a, b, c, *(fig. 27) it is required to place the point d in the plan conformably to the position of the point* D *on the ground.*

The table being horizontally disposed at D, lay a varnished and very transparent piece of paper upon it, taking care that it is well stretched, and cannot move about. Fix a needle at any point *d* on this piece of paper, and, after making that point correspond with D, turn the index round the needle, in order to direct it successively to the points A, B, and C; draw in the same directions, on the varnished paper, the indefinite lines *d e*, *d f*, *dg*, which will evidently form the same angles as the visual rays D A, D B, D C, which they represent.

This done, remove the transparent paper, and lay it again on the plan, taking care, as before, that it is well stretched; but this time, the indefinite lines *d e*, *d f*, and *d g*, must respectively and very accurately pass through the points *a*, *b*, and *c*; in which case, the point *d* will be situated in the same manner, respecting these points, as D with regard to A, B, C; thus it will suffice to prick *d* from the transparent paper.

This operation is sometimes performed by means of a kind of compasses with three legs and various additions, the construction and use of which can scarcely be clearly understood from a written description alone; wherefore we shall not attempt to give any; besides, it seems that the other method has several advantages over this instrument.

Application of the two last preceding Problems to an Example.

Suppose the principal points A, B, C, D, &c. of a country, *pl.* 4, *fig.* 28, to be already described on the table, and that, in order to fill up the plan, it is proposed to take intermediary points, such as H, for instance; the table being properly disposed at H, this point may be taken by either of the methods explained in the two preceding problems, and be used afterwards for determining others; the same may also be done with regard to any other point, and the plan be thus filled up. We shall observe, however, that principal points should, as much as possible, be employed for this purpose, in preference to intermediary ones; the reason is that those points indispensably require to be be very carefully laid on the table, wherefore the accuracy of their respective positions may be particularly depended upon; besides, even supposing that an error was committed in placing one or two of them, this error will only affect the operations performed by means of these few wrong points; whereas, on the contrary, if an intermediary point, inaccurately determined, is used afterwards for determining one or several others, not only the latter will be affected by the inaccuracy of the former, but also every other point which they may subsequently serve in taking; and so on.

In order to describe the course of the river *a*, *b*, *c*, *d*, &c. the table should be successively placed at the principal windings *b*, *c*, *d*, &c. and these points be taken; then, visual rays may be directed from the same points along the bank, and the lines *b c*, *c d*, &c., which represent them, being drawn in the plan, these lines will give the course of the river;* with regard to its breadth, some remarkable objects in those parts of the opposite bank, where the breadth varies the most, may be easily taken by intersection from such of the stations *b*, *c*, *d*, &c. as are the best situated for that purpose.

Further Illustration of the Use of the Plane Table.

The various methods of surveying with the Plane-table, which are generally used, have been separately illustrated in the preceding pages, and it now remains to explain in what manner they may be alternately employed in the same survey, according as circumstances render one of them more convenient than the others.

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* The particular formation of the bank is generally described as it appears to the eye, but should greater precision be required, the perpendicular distances of the lines *b c*, *c d*, &c. to the bank must be measured, and transferred to the plan as has been explained in page 41.

Suppose that the positions of the principal points A, B, C, D, (let us say four steeples) of the country represented in *pl.* V. *fig.* 34, are given on the paper of the table, as well as the direction of the magnetic meridian; and that it is required to throw in the details of the ground between the villages C and D.

The table being horizontally disposed at E, and rectified, determine this point by one of the two problems, at pages 42, and 43;* then, direct the visual rays E F, EG, EH, along the roads which meet each other at E, and after drawing the lines *e f*, *e g*, and *e h*, which represent those rays in the plan, *fig.* 35, measure E H, and set off from *e* to *h* its corresponding length taken from the scale; place the table at H, according to the directions already given, and draw the visual rays H L and H I.

This done, the point I might be determined by measuring H I, and then setting off its corresponding length from *h* to *i*, conformably to the *first method*, page 28; but the operation will be performed with greater expedition by means of the *second method*, page 32; that is, by rectifying the table at I, and turning the index round a needle fixed at *e*, until the staff, or any other signal placed at E, is seen through the sights; from I draw the visual rays I K and I L, the latter of which will cut the visual ray H L previously drawn, and give, therefore, the position of the point L by the *third method*, page 34, without any measurement being requisite.

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* Should not the direction of the magnetic meridian be traced on the paper, the point E must be determined by the problem at page 43, as the other is not suitable to this case; we may also, if we prefer it, take that direction, by means of the given principal points, before we begin the operation. *See page* 43.

The table being removed to K, and rectified, the point L, or rather its corresponding point *l* in the plan, may be used in order to determine the distance I K by the *second method*, and, consequently, the measuring of this distance will also be avoided; then visual rays should be directed from the same point K, along the roads M, N, and K O; and if the table be next rectified at L, and the visual ray L O drawn, the intersection of the latter with the visual ray K O will give the point O; and so on.

The general features of the ground, such as they appear to the eye, are to be described in the plan, as the survey is carrying on; but, should we wish to determine the position of any particular point more accurately than by the eye alone, this may be done, according to circumstances, either by means of one of the two problems given at pages 42 and 43, or by any other convenient method.

For example, suppose we wish to fix the position of the bridge F, in the direction of which the visual ray E F was drawn in the beginning of the survey; if, after determining the point H, and rectifying the table at that point, we draw the visual ray H F, the intersection of this ray with E F will give the position of the bridge by the *third method*; the eminence R may also be taken from L and O by the same method, as well as the farmhouse S from K and O. Lastly, should an object T be conveniently seen only from R and O, we may, likewise, take it by intersection from these points.

Should an accurate description of the villages C and D be required, the table must be successively placed at such points of station within them, as will allow visual rays to be drawn in the directions of the streets, which ought then to be measured, and their dimensions set off in the plan, the buildings on both sides being represented. With regard to the gardens, orchards, fields, hedges, &c. adjacent to the villages, a station may be made at each corner of the ground, as in the *first method*, or any convenient polygon may be traced round each village, and the process explained in the problem given at page 40 be used. Towns may evidently be surveyed in the same manner.

It is by using alternately, as circumstances may require, all the methods of surveying with the Plane-table which have been explained, that the details of a country are taken; every point, as it is determined, affords new means, and therefore greater facility for determining others. Thus the work becomes less and less embarrassing as the survey advances, and a complete topographical description of the country is at last obtained.

In order not to omit any particulars which may be conducive to a full illustration of the use of the Plane-table, practical means of supplying the magnetic needle, in such circumstances as will not allow us to employ it for rectifying the table, shall now be pointed out.

Suppose that the principal points of the country where the survey is carrying on, are given on the paper of the table, and that we are placed at one of those points; suppose also, that we see several other principal points from this station, or, at least, one of them.

The index being laid on the paper, in the direction of the point of station and one of the other given points, the table is to be rectified by turning it about until the object which corresponds to the latter point is seen through the sights; a visual ray is then to be directed to any object we may wish to take, and the distance of this object measured in order to set it off from the scale on the line which represents it in the plan. After which, the table may be removed to the object, and rectified by means of the aforesaid line and distance, or rather by using for this purpose the last point which was determined, and such principal point as is seen from the station, in order to take another object, and so on. This method of rectifying the table is evidently founded upon the same principles as that explained at page 43, and it is equally obvious, that the necessity of measuring distances may also be occasionally avoided in this case, by taking some of the points by intersection, conformably to the *second* and *third methods* of surveying with the Plane-table; or by the problem given at page 43.

Description and Use of the Compass.

The Compass, *pl.* V. *fig.* 29 is an instrument consisting, like the *Declinatoire*, of a magnetic needle placed in equilibrio upon a very fine point, and enclosed in a square box on the interior of which a circle is described and divided into 360 degrees; it is even useful to have the circle divided into half degrees. The four cardinal points are marked at the bottom of the Compass, in such a manner that the north and south line, which is numbered 0° and 180°, is parallel to one of the sides of the box. To one of these sides, an index with sights or a telescope is adapted, which is capable of taking any inclination to the horizon, without, however, moving in any other plane but that which is perpendicular to the graduated circle. The compass is moveable on a support, fixed to a foot with three branches, and may be detached from it, in order to make it serve for the same purpose as the *Declinatoire*. The Compass affords the surveyor more advantages than any other instrument, for expeditiously surveying all the objects destined to fill up and ornament the small tracts taken with the Plane-table, or for military reconnoitring.

In observing with this instrument, it must be brought to the horizontal position, and constantly pointed from the same side, in order to avoid mistakes; that is, the index must always be brought to the right or to the left. Then the degrees are reckoned consecutively from 0° to 360°.

Little need be said relative to the use of the Compass, as the principles previously explained here find their application, and it would be sufficient, strictly speaking, to shew the method of measuring the inclination which any line on the ground has to the magnetic meridian; but, as this work is designed to be useful to those who are unacquainted with the art of taking plans, we shall resolve the following important problems.

To take the Plan of a Polygon A B C D E F, *pl. IV. fig.* 30, *all the points of which are accessible.*

Place the Compass horizontally at the point A, and turn it on its pivot until the point B is in the direction of the sights or of the optic axis of the telescope. After the oscillations of the needle have ceased, it will take its *northerly* direction. Thus, by reckoning, according to the natural order of the numbers of the division, the number of degrees from the visual ray A B, or, which is the same, from the zero on the *north* and *south* line, to the northern point of the needle, the measure of the observed angle will be obtained. The contour of a wood, a marsh, a morass, &c. may evidently be surveyed in the same manner.

Unless we propose to transfer immediately to the plan, the series of measures taken on the ground, the number of degrees found at the point A, ought to be written on a rough sketch, as in *fig. 31*; and, supposing the line ab, in the same *figure*, to represent the direction A B on the ground, the number of yards contained in A B should also be written along that line. The Compass is then to be placed horizontally at the point B, and the inclination of the line B C observed, taking care to write the measure of this inclination at the point b on the sketch. The work is to be continued in the same manner until we return to the first station A.

One method of proving that no material error has been committed in measuring the angles, is to ascertain if the sum of all the interior angles of the polygon is equal to twice as many right angles, wanting four, as the polygon has sides; but, how are these angles to be known, since they have not been immediately observed? The answer to this question is easy. The directions of the magnetic needle being considered as parallel for all points of the plan, the angle abc, for example, will be equal to $nab + s'bc$; but $nab = 360^\circ - 319^\circ\,30' = 40^\circ\,30'$, and $s'bc = 278^\circ\,6' - 180^\circ = 98^\circ\,6'$; therefore $abc = 40^\circ\,30' + 98^\circ\,6' = 138^\circ\,36'$; and the same for the other angles.

With respect to the verification of the sides, it cannot be accomplished until the polygon is constructed by means of a scale and a protractor. It will then be seen if the figure has been well formed.

The Compass is also used to advantage, as will be seen, for surveying the course of rivers, as well as the turnings of roads, and, in short, all the minute details of the same description; but, when we employ this instrument, jointly with the Plane-table, the details taken with the former should be instantly transferred to the latter, as by this means the requisite rectifications will be perceived and made with greater facility. Besides, the form of the ground, which we have within view, or of which we have a perfect recollection, will be better expressed; it is proper, also, that the work at large should be penned in every evening, that it may not be defaced by the proceedings of the subsequent day.

Since, in a small space, all the magnetic meridians may be regarded as parallel to each other, it follows that it is not absolutely necessary to make a station at the vertex of every angle of the polygon. For example, the observation at B may be dispensed with, because, from knowing the inclination of B C to the meridian $s''n''$, that of the same side with respect to the meridian at B will also be known. In fact, since the interior angles on the same side are supplements to each other, the number of degrees found at the point C exceeds that which would have been obtained at the point B by 180°. Thus, when, in the construction of the figure, we wish, at the point *b*, to determine the direction of *b c* by means of the observation made at C; the number on the protractor must be taken that is diametrically opposite to that which has been found at the point C: in this manner the number of stations is greatly diminished.

Two Points A, B, *on the ground, fig.* 32, *being given upon the Map in* a *and* b, *fig.* 33, *besides the direction of the magnetic needle relatively to the right line* a b, *to determine the station* M *upon the same Map.*

Measure the inclinations of the visual rays M A, M B, at the point M, with respect to the magnetic meridian, and draw upon the map the meridional lines $s\ n$, $s'\ n'$. This being done, in order to fix the inclination of $a\ m$ with respect to $s\ n$, the number diametrically opposite to that found at the point M is to be taken. The same is to be done with respect to the line $m\ b$, and the intersection m of the two lines will be the point required.

If more than two points were known, it would be proper to verify the operation, by drawing other visual rays, and determining in like manner their directions on the map. These new rays would also pass through the point m; at least, if no error had been committed in either the former or the latter operation.

Among other methods, that which is here explained may serve to fix several points of the crests of mountains, the positions of elevated planes, the commencement and termination of declivities, &c.

To take the Course of a River with the Compass.

Suppose it is required to take with the Compass the course of the river represented in *pl.* V. *fig.* 36.

Staves being planted at the principal windings A, B, C, D, E, F, G, H, of the river, and the Compass successively placed at each of those points, the angles a AB, *b* B C, &c. which the lines A B, B C,* form with the direction *a* A, *b* B, &c. of the magnetic meridian, are to be observed in the manner already explained, and those lines be measured. All the angles and distances being thus known, the plan is to be made as follows :—

Draw any line *a′ a*, *fig*. 37, representing the direction of the magnetic meridian, and after taking any point *a′* in this line, to represent the point A on the ground, describe at *a′* the angle *a a′ b* equal to the observed angle *a* A B ; set off from *a′* to *b′* the number of measures, taken from the scale of the plan, which A B contains, and draw *b′ b* parallel to *a′ a* ; then describe the angle *b b′c* equal to its corresponding angle *b* B C, and *b′ c′* being made equal to the number of measures found in B C, proceed at *c′* as you did at *a′* and *b′*, and so on ; the lines *a′ b′*, *b′ c′*, &c. will give the course of the river, and with regard to the particular delineation of the bank, see the note at page 45.

What has been said respecting the method of taking the course of a river, is evidently applicable to the turnings of a road.

Should you wish to determine the breadth of the river facing the point M which is close to the opposite bank, or should this point be a remarkable object which you propose to take ; draw to it from A and B the visual rays A M, B M, and observe the angles *a* A M, *b* B M, which those rays make with the directions *a* A and *b* B of the magnetic meridian ; then describe these angles in the plan, and the intersection *m* of the sides *a′ m* and

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* It is scarcely requisite to observe that the lines A B, B C, &c. represent the directions of the visual rays drawn from each station along the bank of the river.

$b'\,m$ will give the position of the point M; the small island N may also be taken from A and B in the same manner.

Description and Use of the Cross-Staff.

Land Surveyors commonly use a Cross-staff for determining offsets, and even for taking plans of small estates, and insulated pieces of ground of moderate extent; this instrument is very simple, and generally consists of two brass rulers, *pl.* VI. *fig.* 38, cutting each other at right angles in the centre, the extremities of which carry four sights perpendicular to the rulers: or of a brass circle divided into four equal parts by two lines crossing also each other at right angles in the centre, at the ends of which the sights are placed in a direction perpendicular to the plane of the circle. Sometimes too, the sights are pierced out in the circumference of a thick tube of brass, about 2½ inches diameter, and in this case the instrument is called a *Box Cross-Staff.*

The cross is frequently screwed on a single staff, which has a sharp point at bottom, that it may be stuck in the ground; but it is preferable to have it supported by a stand with three legs, upon which it has a rotary motion.

The accuracy of the Cross-staff depends on the sights being exactly at right angles to each other, and in order to ascertain that they are so placed, look at one object through two corresponding sights, observing at the same time, without moving the instrument, another object through the other two sights; then, turn the cross upon the stand, and look at the same objects through the opposite sights; if the former are exactly in the directions of the latter, the instrument is correct, and may be used as follows.

Suppose you wish to take a plan of the field or any other piece of ground A, B, C, D, &c. *fig.* 39, the inside of which is accessible; draw the base A X across the field in the direction of its length, and let fall the perpendiculars B B′, C C′, D D′, &c. to this base, from the angles of the perimeter. Then measure these perpendiculars, either with a chain or with rods, as well as the distances A B′, B′ C′, &c. between them, and write down in a rough sketch all the lengths thus found, as is shewn by the figure. It is to be observed, that, as the base and perpendiculars divide the field into triangles, trapeziums, or rectangles, its area may be easily computed according to the principles of the mensuration of superficies.

To draw the plan, *fig.* 40, take from the scale, and set off from *a* to *b′*, from *b′* to *c′*, &c. on any line *a x* the corresponding lengths to the distances A B′, B′ C′, &c. *fig.* 39; then erect at *b′* and *c′*, &c. the perpendiculars *b′ b* *c′ c* to *a x*, and make them equal to the number of chains or rods, taken also from the scale, which B′ B, C′ C, were found to contain; lastly, connect the points *a*, *b*, *c*, &c. in the plan, in the same manner as the points A, B, C, &c. which they represent, are connected on the ground.

When the ground to be surveyed has a certain extent, and the boundaries are very crooked, the above method requires a great number of partial measures to be taken, which operation is sometimes attended with difficulties, particularly if the perpendiculars are let fall from points which cannot be easily approached in their directions; but this inconveniency may be frequently removed in the following manner:—

Should it be required to take a plan of the ground Z, S, Y, N, P, &c. *fig*. 41, draw at any convenient place within it the two bases B Z and X Y, cutting each other at right angles. Then walk along one of them, the base B Z, for instance, and let fall the perpendiculars G Q, F P, E O, D N, &c. to this base from the angles of the perimeter; measure the distances of these perpendiculars from the point of intersection A of the bases, and write them down in a rough sketch. This done, walk along the other base X Y, and after letting fall the perpendiculars P P′, Q Q′, N N′, O O′, &c. from the same angles as before, measure also their distances from the intersecting point A. Now, it is evident that the distances in one base are respectively equal to the perpendiculars let fall to the other; for instance, A P′ is equal to P F, and A Q′ to G Q; and so on. Thus it is not requisite that any perpendicular should be actually measured; wherefore, even inaccessible points may be taken, and the formation of the plan will only require the construction of rectangles.

Nay, it is not absolutely necessary that the two bases should cut each other at right angles, although it is proper that the angles which they make should not widely differ from right angles; care must only be taken, in describing the plan, that the lines representing the bases form exactly the same angles as in the operation. *Fig*. 42 shows the method of proceeding in this case, which is particularly convenient when we are obliged to trace the bases on roads, dikes, &c. that are inclined to each other.*

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* The methods of surveying with the Cross-staff, here explained, give by construction the values of the lines which connect the objects, and of the triangles which they form; but it is easy to obtain

some practical methods of performing this operation, with the simplest instruments, and in the most common cases.

The most simple instrument that can be employed for levelling is the Water-level, *pl.* VII. *fig.* 47. It consists of a cylindrical tube A B, the extremities of which are bent, and support two phials, or small glass cylinders C, D, open at both ends: this tube is mounted on a foot with three branches, in such a manner, that the instrument may be inclined, elevated, depressed, or turned horizontally at pleasure. Water levels are generally made of tin, but those of brass are the strongest and most commodious.

When this instrument is to be used, the water is poured into one of the phials, and immediately communicates with the other by means of the tube A B; and a sufficient quantity is to be poured in to fill the two phials about two-thirds full. When the water ceases to be agitated, the two surfaces may be considered as being level; provided there are not any bubbles of air in the interior of the tube. In order to expel these bubbles, one of the phials is to be stopped, and the instrument inclined until the column of fluid becomes nearly vertical; by which means, all the air it may contain will escape through the other phial. The instrument does not require any other verification.

It is important that the phials should be of very transparent glass, and have the same dimensions; and also that the water should not escape from the level during the operation, through the places where its component parts are united. Finally, it is necessary, especially during great heats or heavy rains, that the time of observation at each station should be short, in order that the water may not be diminished by evaporation in the one case, or increased by the rain in the other. The water is often coloured to render it more apparent.

When the level is to be removed from one station to another, one of the phials must be stopped, and the instrument inclined, to prevent the water from being spilt; for, if we are obliged to renew it frequently, the operation of levelling takes a much longer time, on account of the necessity of ascertaining that the tube does not contain bubbles of air. It is also by stopping at intervals one of the phials with the finger, and afterwards taking it gently away, that we gradually diminish the oscillations of the aqueous column, occasioned by the motion imparted to the instrument in directing it to the vane.

With the Water-level, a very straight rectangular staff E F, *fig.* 48, called a *Levelling-staff*, is used, along which a rectangular piece of wood G slides at pleasure, which is called a *vane*, having each half differently coloured. The Levelling-staff is so graduated as to give feet and inches upon one of its faces, and tenths of inches upon the collateral faces.

The Water-level is used in the following manner:—

To determine the difference of Level of two points, A *and* B, *fig.* 49, *with the Water-level.*

The level C P being placed nearly at equal distances from A and B*, and the assistant holding the levelling-staff vertically at A, place yourself at a small distance from the instrument. In this situation, the lateral surfaces of the *onglets*, (or upper horizontal sections,) formed by the water in the phials, will appear like dark lines drawn horizontally upon the glass. Direct along these lines the visual ray, which will, consequently, be a tangent to the exterior surfaces of the phials; and make the proper signs to your assistant, for raising or depressing the vane, until the visual ray falls upon its middle. Then read on the staff the number of feet, &c. contained in the height Aa, and write it upon the rough sketch of the levelling.

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* The level is placed nearly at equal distances from A and B, in order to avoid the corrections arising from refraction and the difference between the apparent and true level; but the station point C may, without inconvenience, be out of the right line *a b*, which represents the horizontal distance from A to B.

Without deranging the foot of the instrument or losing any time, remove the levelling-staff to the point B, and proceed as before, in determining the height B*b*. Now, it is evident, that, if the heights A*a* and B*b* be equal, the points A and B are level; but if the height A*a*, for example, $= 3^{ft.}\ 7^{in.}\ .3$, and that of $B\,b = 2^{ft.}\ 5^{in.}\ .2$, the point A will be lower than the point B by the quantity $A\,a - B\,b = 3^{ft.}\ 7^{in.}\ .3 - 2^{ft.}\ 5^{in.}\ .2 = 1^{ft.}\ 2^{in.}\ .1$.

To take the Profile of a Ground.

When the ground between the points A and B, *fig.* 50, is uneven, and the profile of it to be taken, the levelling staff must be placed successively at the points A, C, D, E, B, for the purpose of obtaining their respective altitudes; and we likewise measure the height P*o* of the instrument, supposed to be placed upon the right line *ab*. Lastly, we determine the horizontal distances *ac*, *cd*, *do*, *oe*, *eb*. It is customary to make these distances equal to each other, when the ground is only slightly undulated, and the bendings of the different slopes are but little sensible.

If we have an intelligent assistant, he may be entrusted with writing the results of the different measurements himself upon a register. Nay, it is requisite that he should write them, when we can correspond with him only by signs. Nevertheless, the leveller should not neglect, on his part, to collect all the measures, and even, if he has time, to make a figure of the profile, in order to ascertain that his notes, and those of his assistant, agree perfectly together.

The survey of a profile being made, it is to be laid down according to the adopted scale; but, when the different heights are very small in comparison with the horizontal distances by which they are separated, they are all to be increased by the same quantity, in order that the space between the horizontal line which indicates these distances, and that which represents the surface of the ground, may more easily admit the respective heights to be inserted upon the profile. For the same reason, the heights are often laid down from a larger scale than that used for the horizontal lengths; generally, the scale for the heights is a multiple of that employed for the lengths.

Description of a very simple Instrument, resembling a mason's level, by means of which the inclination of a line, or of a surface, may be easily determined in taking the details of a country, and zenith distances be measured. On the methods of using this instrument for the above-mentioned purposes.

The reader knows, that the level, *fig.* 51, which is used by masons for placing free stones or bricks in horizontal layers, is composed of three principal rulers, AC, CB, DE, the first two of which are equal to each other; and he is aware, likewise, that the surface upon which this level is placed is horizontal, when the plumb line CP, suspended from the vertex C of the triangle ACB, corresponds to a hole cut exactly in the middle of the horizontal ruler DE.

The instrument ACB, *fig.* 52, the construction and use of which are now to be explained, resembles a mason's level and is used, in taking details, not only for ascertaining the inclination of a line or a surface, but also for measuring zenith distances. When it is used for the first of these operations, it has two sights at its extremities A and B, or else a telescope is adapted to it, similar to that of the compass, page 49, and the line AB is divided into parts equal to those on the perpendicular CD. We generally conceive CD=1000 parts, which are carried to the right and left of the middle point D of the ruler AB, and numbered as represented in the figure.

For measuring zenith distances, a graduated arch of metal, having 180° of amplitude, and the point C for its centre, *fig.* 53, must be adapted to the instrument instead of the graduated line AB, above mentioned. The graduation of this arch is numbered so as immediately to give the zenith distances. In fact, suppose the index placed along AB, to be directed to the object H, and the plumb-line to fall upon the number 75, the divisions being on the right of the observer; in this case, the apparent zenith distance of the object H, or the angle HAZ, will be 75°, since it is the complement of HAK, or of mCD, $=90°-15°=75°$. It is, therefore, evident, that the object H would appear to be in the horizon of the place of observation, if the plumb-line fell upon the division numbered 90, and that it would be below this plane, if this line passed through a division comprised between 90 and 105; but it is not necessary, in this case, to mark whether the object is above or below the horizon, because the measure of the zenith distance always shows this.*

The manner of using this instrument in performing each of the above-specified operations shall now be explained.

First, suppose it were required to determine the difference of level of the two points X, Y, *fig*. 52.

The instrument being placed upon its stand, and fixed at X, the index AB, turned to the right of the observer, is to be directed to the levelling staff placed at Y; then a visual ray AH is to be drawn to the middle of the vane, and when the plumb line has ceased to oscillate, the number of parts marked by this line is to be reckoned. This number diminished by 1000 will give the distance ED; so, in this example, the point H will be higher than the point D. But, should the plumb line fall between B and D, as the number marked by this line would then be negative, it would indicate a depression; that is, the point H would be lower than the point D. This shews the advantage of numbering the divisions as represented in the figure.

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* Rods, that are placed end to end for measuring bases, are almost always inclined to the horizon, and in order to reduce their lengths to the level of one of their extremities, the inclination of each must be ascertained. The instrument above described gives the inclination immediately, but then, the divisions are numbered from 0 to 36°, so that the middle point of the arc answers to 18°; and instead of a plumb line, a small air level is adapted to a branch moveable about the centre C, in such a manner, that, when the bubble of air is in the middle of the tube, the ruler may be vertical. When the level is placed upon the ruler, the degrees marked by the index of the moveable branch are observed. The level is then reversed, in order to observe again the degrees indicated by the index, and half the difference of the two observed numbers is the measure of the ruler's inclination. By this method the error which affects the result is less than if we had observed the angle only once. Care should be taken to indicate by the sign + or — the angle of elevation or depression of the point B.

The height H m above the horizontal line D m yet remains to be determined. For example, let $ED=380$ parts, and the measured horizontal distance $Dm=150$ yds. The triangles E C D, m D H are similar, for they are both right-angled, the one at D and the other at m; besides, the angles F E D, D H m, are equal to each other, on account of the parallels C F, H Y: therefore, by comparing the homologous sides, we have given

$$CD : DE :: Dm : mH,$$

and by substituting the numerical values,

$$1000 : 380 :: 150^{\text{yds.}} : x = 150 \times 0.38 = 57 \text{ yds.}$$

The two lines C F, H Y are the respective verticals of two different stations; so that, strictly speaking, these lines cannot at the same time be perpendicular to the horizontal line F m drawn through the point D; but the length of the visual ray A H is always so small in respect to the radius of the earth, that C F and H Y may be considered as being parallel to each other. In the case where the distance D m would exceed 330 yards, and it is requisite to take the effect of refraction into the account,* we must proceed according to the methods explained in the first volume of this work.

The use of this instrument is equally easy, when employed to measure zenith distances.

Suppose, for example, that we had found 86° 10′ for the zenith distance Z A B, *fig*. 54, of the point of direction

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* The effect of refraction is scarcely to be considered for a smaller distance than 330 yards.

B, observed at the point A; and that the horizontal distance A D=325 yds.=K; the angle B being equal to the zenith distance, which is denoted by δ, and the triangle A B D being very nearly right angled at D, we have

$$\text{Sin. } \delta : K :: \cos. \delta : D B = \frac{\cos. \delta}{\sin. \delta} K = K \cot. \delta.$$

When δ is less than a quadrant, B D is positive, and consequently the point B is above the horizontal line A D. This point, on the contrary, is below the horizon of A when δ is greater than a quadrant.

This formula shews that the elevation or depression is *very nearly* equal to the horizontal distance multiplied by the co-tangent of the observed zenith distance; we say *very nearly* equal, because great accuracy would require that the effect of refraction should be taken into the account; but, as was already said, this effect may be neglected whenever the distance of the object does not exceed 330 yards, and especially if the instrument above described be used; for the zenith distances measured by it will not be strictly true, however precautious the observer may be in taking them, and consequently it ought to be employed for this operation only in cases where great precision is not absolutely requisite. One of the circumstances in which it will be found very useful is that where, in taking the details of a country, we wish to know nearly the heights of several surrounding points near the stations, in order to be able to form the relief of the ground which has been surveyed with the assistance of the plane-table, of the compass, or of any other instrument.

We shall terminate this section with an example of the calculation of the preceding formula.

Let K=246 yds. δ=86° 30′; then using logarithms, and taking only five decimals, which are sufficient, we shall have

$$\begin{array}{r} \text{Log } 246 = 2.39093 \\ \text{Log. cot. } (\delta = 86^\circ\, 30') = \underline{9.33962} \\ \bar{1}.73055 = 53.77 \text{ yds.} \end{array}$$

Thus the relative height found is equal to 53.77 yards, which gives the elevation of the point of direction B above the level of A. In order to have the real height of the ground above the point of station, B D must be diminished by the height of the point of direction, and the height of the instrument be added to the remainder. Precisely the reverse takes place when B D is a depression.

It should be remarked, that, by the height of the point of direction is to be understood, that from the extremity of the visual ray to the level of the ground; and by the height of the instrument, that from the point D, *fig.* 52, to the line X Y. If a signal were placed at the point Y, the height of the signal would represent that of the point of direction.

PART IV.

AN ESSAY
ON
MILITARY RECONNOITRING.

MY endeavour is to present military reconnoitring, its objects and applications, in the most general point of view; and especially to unfold and promote a method which, as well as the means of observation connected with it, is simple, abundant in results, and worthy, I trust, to fix the attention of officers.

This method requires some elementary knowledge of several sciences which have only an indirect relation to war; but, instead of supposing the reader to possess that knowledge already, I shall explain the subjects which it embraces, and reduce them to what a military man ought indispensably to know: whatever requires any particular study is thrown into notes, and even these notes are so conceived, that a little judgement will be sufficient to peruse them to advantage.

Indeed, theory alone will not supply the place of practice; *coup d'œil* in war, quickness of perception in administration, and taste in the fine arts, cannot be imparted. But in war, as in other things, theoretical instruction abridges the time of trials, quickens the acquirement produces, and their quality; the contributions which it can furnish; the materials and number of hands it can afford for sieges and other requisite military employments. In short, government must know the best means, not only of taking those resources from the enemy, but also of collecting and even augmenting them without bearing too much upon the inhabitants, and thus causing them to revolt: proper information on this point may be obtained from the administrative system of the country, and from all the documents collected either by the inhabitants or by others, upon the sources and extent of national riches.

In order to obtain success in war, we sometimes have recourse to politics, and benefit by the hatred, factions, civil dissentions, ambition of individuals, and such differences with regard to customs, religion, and opinions of all kinds, as may be found among the same people; the conquest of a country may also be consolidated, and the security of the victorious army established, by taking advantage of the disaffection of the inhabitants to their government, of their love to the new laws, and of their fear of returning to the former order of things.

War is still connected by other links with the secret views of government, as no proper stipulations for the lines of boundary and neutrality can be made in treaties or conventions of any kind, without attending to all military considerations. Is a neighbouring people our natural ally, or enemy? will he not be one or the other according to circumstances, and as his interest may require? have we only to defend ourselves, or is it proper that we should wage an offensive war? are the aforesaid lines to follow the ridges of mountains, so that we may remain in possession of the declivities on our side? or, may particular considerations lead us to give up the summits of the heights opposite to us? when may we satisfy ourselves with occupying the banks of the great rivers and canals, and in what circumstances should we advance beyond them? Finally, what is the suitable direction of the lines of boundary and neutrality towards the points where frontiers of a different nature meet?

If government must have such a knowledge of the enemy's country, it is still more requisite that it should know its own. Both a defensive and an offensive war require the same kind of information, and, also, that it should be applied in a similar manner:—"Do," said a great general, "all that your enemy fears; not what he desires." But how extensive this precept is, and how difficult the application of it appears, although the precept itself may be so easily remembered!

Other important objects also demand the consideration of government: I allude to those permanent and long-continued works which a state may execute, at least upon its frontiers, with a view to favouring its future defensive and even offensive operations; the relations which fortresses, already constructed, have with the movements of armies, have been previously mentioned. But, in the case now before us, government is to examine at what points those in contemplation should be erected, according to the purpose which they are intended to answer, as defensive and offensive operations may require different combinations on this subject; for instance, strong places, which are to serve for depôts, ought, in a defensive war, to be situated at a certain distance behind the frontier, whilst, on the contrary, in an offensive war, they should be placed upon the extreme frontier, so as to occupy the line of departure of the invading army, favour it in passing the rivers, protect the debouchés of every description, shorten the lines of operations, and extend their radius of activity far into the enemy's country.

have with the countries surrounding them, are analogous to those of the metropolis; but their distance, the obstacles arising from the nature of the territory, and the difficulty with which such colonies can receive any kind of succours, frequently augment the importance of those relations, and render the measures which should be employed more difficult to take. Whereas, on the contrary, the insulated situation of an island allows the system of its defence to be modified, and all the proper maxims for maritime frontiers to be applied to its whole circumference, by choosing one or several central points, according to the extent of the island, from which defensive or offensive operations are to be carried on, as circumstances may require; for, the defenders not only can act offensively, but should attack the invaders as soon as they set their foot on the shores.

The military problems, relative to the various situations of which we have been just now speaking, become more complicated from the addition of naval considerations; wherefore, the number of data, which government has need to collect in order to resolve them, is greater.

Thus, all the branches of the administrative system of a country are connected with each other; and when every department exerts itself in ameliorating that part of the public service which is particularly intrusted to its care, the head of the State, who is to direct the whole machine of government, unites those separate results together, and considers not only their direct effect, but their mutual effect also.

ARTICLE II.

Continuation of the same Subject.

NOTHING has been said of government which is not applicable to the War Minister;* placed near the chief of the state, and being the first depositary of his thoughts, he puts his wishes in action, and watches their execution.

The commander of an army should possess more or less of the above-stated particulars, according to the object of the campaign, and the country where he is to act; nay, his information ought to be still more precise, and especially to embrace a greater number of details. Indeed, government has composed the army according to the country which is to be the theatre of war, and secured the means of supplying it with provisions; it also has rendered itself certain that this army will not meet any very great obstacles, or, at least, that it will be able to overcome them. But general, and sometimes incomplete notions may have appeared sufficient for regulating the dispositions of government to that effect, and actual operations require a more accurate information, as well as details far more comprehensive: it will not suffice that one thing be possible, but it must be done; the army every day must be fed, must encamp, march, or fight; the sick and wounded must have an asylum and receive assistance; the army must be recruited, and its clothing renewed at certain times; all this must be done, let the circumstances at large be what they may; and government cannot foresee every thing; nor is it requisite that it should: the object of war is known, the lines of departure and operations are determined, and the subsequent events will depend on talent or fortune. Besides, some deviation from the original plan will always be found requisite in its execution. How can we foresee every movement which the enemy may make? such great ideas as an adversary, who possesses considerable genius, may suddenly conceive? the unexpected faults that may be committed, and those fortuitous events in which chance seems to defeat all combinations?

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* The author alludes to the War Minister in France, the functions of whom are much more extensive than in several other countries.

War is declared, and the armies assemble; but what position does the enemy occupy? How are we to judge of his designs? Where are his magazines? Whence come his convoys, and what roads do they follow? At what points is he forming his depôts? And if, in order to keep us uncertain of his views, he makes similar dispositions on two different lines, if he threatens several points of our frontier at once, by what signs are his true projects to be discovered? On the other hand, what movements, what preparations, and what demonstrations does the nature of our country allow us to make, as well as our fortresses and other establishments, in order to persuade him that we are ready at all points? How can we deceive him, or, at least, cause that uncertainty in his mind which he wished to create in ours?

It was said that the army must be fed, and clothed. Now, if the enemy's territory be invaded, what resources will it afford? A general information upon this head will not be sufficient, as we must know distinctly the nature and quantity of the different produces; where they are to be found, and what are the proper places for collecting, preparing, and distributing them to the troops. What establishments, manufactories, workshops, and machines, every province, every town, and even every village, contains. Lastly, what is the quantity of military stores of all kinds, of beverage, and other articles of subsistence, which, in case of need, may be instantly provided for the army?

Sometimes even, when war is carried on in a country which is poor and without industry, they are the elements constituting the manufactures that should be known, as well as the materials, means, and number of hands requisite to create them, to put them in a state of activity, and to maintain them.

It is not sufficient that magazines are or can be formed at intervals upon the line of operations, as the army must be supplied with provisions and ammunition in all its movements; means of conveyance will also be required for other branches of the service, such as the equipages belonging to the troops, the train of artillery for sieges, the apparatus for bridges, the parks and moveable hospitals; and, as it rarely happens that the army itself is sufficiently provided with those means, the country must supply the deficiency, and sometimes afford the whole.

The roads, canals, and rivers, which the convoys are to follow, are known beforehand, as well as the points where they may arrive by sea with the smallest difficulty; but it is important to ascertain exactly the quantity of boats and vessels of every description which may be collected; or, if the convoys are to go by land, the number of carts, horses, and other beasts of burthen; also the breadth of the roads, and the width of the bridges and sluices. Lastly, we ought to be acquainted with the parts of the country where carriages can travel, those where mules only can be employed, and with the passages in traversing which we cannot transport any thing except by the hands of men: all these details should be accurately known.

Such are the principal subjects of information relative to the army itself, which the general who commands it must possess. But actual military operations require a great many more considerations.

The army is to be put in motion, and the principal roads which will favour its advancing are known; but it still remains to regulate the order of march, the formation of the various columns, and to assign to each of them the road which it must follow. The choice of roads requires a great many considerations: here every thing favours the army; a country easy to march in, excellent roads, convenient bridges, ferry-boats, fords, &c.; there, on the contrary, obstacles of every description are accumulated: a wet, slippery, or a mountainous ground, ravines, thick woods, morasses, roads cut up, bridges and fords destroyed, a neck of land, or a defile which the enemy occupies, will impede, and perhaps entirely stop, the march of the troops; which of these obstacles can be surmounted? Can we not repair the roads in haste, re-establish the bridges, or cross a stream by other means, force a neck of land in the possession of the enemy, turn a defile, and even cut a road through a mountain, if circumstances indispensably require it?

Besides eluding or surmounting the obstacles which the enemy has thrown in the way of the army, his attacks during the march are also to be apprehended. When will the army be able to advance with security? in what manner is it to be directed so as to be, at any time, ready to form in order of battle? what is the enemy doing? what can he do? Not only the roads which the army follows should be considered, but those likewise which the enemy may take; a wood, a long intervening elevation, or a chain of heights, may enable or prevent him from surprising the army in its march, coming upon its flanks, and even routing it, according as they are occupied and properly defended by the latter, or were neglected and badly watched. The enemy will also secure himself by taking the same precautions, or be exposed to destruction if he commits the same faults.

The army halts, encamps, or bivouacs; but, whatever may be the position which it occupies, the proper choice of it requires that the commander should previously foresee and actually know many particulars; the nature, configuration, and extent, of the ground where the army is placed, must suit at all points, the number, wants, service, and manœuvres of the corps which compose it, as well as the immense quantity of equipages, stores, &c. which unavoidably follow it. Besides, even supposing that the camp is to break up almost instantly, and that no attacks are to be feared, yet it is requisite to ascertain before-hand, that the troops will be sufficiently supplied with wood, water, and forage; and should they make a longer stay, that no unhealthy air may occasion sickness in the army, nor implant the germ of any epidemical disorder, which fatigue might afterwards develope, among the soldiers. But, how rarely does it happen that an encamped army is not liable to be attacked openly, or surprised? The enemy is frequently not far distant; sometimes he is superior in numbers, audacious, and enterprising; the camp, therefore, should be so situated as not to be exposed to be turned, and the ground should not render it difficult, beyond measure, to keep proper watch; the country in the rear of the army must be free, and the access to the camp well defended, although without any obstacles which may impede the movements of the troops, should a favourable opportunity of attacking the enemy offer itself. So many conditions to be fulfilled, undoubtedly require numberless considerations:

twenty different positions may be taken within a circumference of no considerable extent, and the same position will allow the army to be disposed in many different ways; the ground at large, and the particulars of it, the artificial obstacles which may be used to advantage, the towns, the villages, the castles, the roads, in short every detail of this kind should be carefully examined; even circumstances apparently trifling may become very important; a ford inaccurately sounded, a by-path which ascends a mountain, or winds under the grass in a wood or a marsh, a low ground which is not seen, a hedge or a corn-field which may hide the movements of the enemy, all these particulars will endanger the security of the camp, and therefore of the army, if sufficient attention is not paid to them; whilst, on the contrary, the encamped troops will derive means of victory from them, if it be the enemy who has committed the fault of observing the country slightly, and thus acquiring only an imperfect knowledge of it.

In general and partial actions, success is frequently owing to the proper information which a commander has of the above-cited details, as it enables him to march unexpectedly upon the flanks and on the rear of the enemy, to place him between two fires, to cut off his retreat, or lead him into ambuscades. On a knowledge of the ground most commonly depend likewise all unforeseen deployments, and those rapid movements by means of which a General surprises the wing which the enemy has weakened, and refuses, breaks his line of battle, and thus insures victory, although he may have been defeated at some points.

The data which the commander of an army ought to collect are different, according to the nature of the operation to be performed.

Suppose it is required to effect the crossing of a river by surprise, by main force, or to prevent the enemy from passing it; in these cases, what bendings will favour us? If their convexity is opposite us, the spot within them, which the enemy defends, would be swept by batteries constructed on our side; but will the nature of the ground allow us to construct batteries? what bank commands the other? does any navigable stream, or any canal, run into the river, where we may collect and conceal our boats? or will the branches of the river, and the islands which they form, answer the same purpose? and in case there should be any towing paths on the side of the enemy, or any parallel roads which may favour our movements, can we take them from him before he is aware of our design, or, at least, before he can secure them to himself? what time does he want, in order to bring down to the spot, first, such of his troops as are the nearest to it, and then his whole army? what is the state of the river at different seasons of the year? how does the water run? what is the velocity of it? in what directions will the men and horses lose ground in the river, and where will they find it again? what method of crossing the river should be preferred? shall we pass it in boats, upon rafts, with leather bags, or swim across it? can we use all these means, or only some of them? what are the enemy's positions, and our own, near the point of landing, in the plain, and upon the neighbouring hills? how can we defend and secure the communition from one bank to the other? what kind of bridges does the river admit of, and what dispositions will its breadth allow us to make, as well as the nature of its bottom and banks, the occasional increase and overflowing of the water, in short, the means, suited to the purpose, which the army carries with it, and those supplied by the countries near the banks?

Moreover, is it requisite that the spot where we cross the river should be fortified, in case our troops should fall back against parties, or against a corps which, after turning those troops, would attempt to cut off their retreat? and if so, can we fortify and defend that spot? is there, on the bank to be defended, a fortress, a town, or a castle, which, with a little expence, will afford us an intrenched camp, a tête-de-pont sufficient for our purpose, or which may be easily improved?

The information which the commander of the army is to procure, and the combinations he ought to form with regard to these works, the temporary places, the posts to be intrenched, and all the field fortifications to be thrown up, are analogous to those which must guide government in its estimation of the system of defence that the frontier requires; it is his concern to decide upon the garrisons and detachments at large which the army can furnish; and also, to determine in what circumstances the ground, the nature of the war, and the movements of the enemy, will allow defensive works to be constructed, and render them useful or disadvantageous. The commander of the army should fix, likewise, the nature and situation of these works, the strength of their respective garrisons, the number of guns, and quantity of ammunition to be appropriated to their defence, so as to secure every advantage, avoid all inconveniences, and strengthen the army in one way, without weakening it in another.

A single fortified town can seldom stop the progress of an army. However, if it be so situated as to serve as a pivot, round which the enemy is manœuvring, what means does the ground offer, in order to drive him away to a distance from it? how can the theatre of war be removed from the neighbourhood of a fortress, the numerous garrison of which makes a powerful diversion in favour of the army which keeps the field? what positions, near or remote, will enable us to place ourselves between this fortress and the enemy, so as to prevent them from communicating and acting in concert with each other? what operations do the ground and fortifications allow us to undertake? will they admit of a sudden attack, require a siege easy to carry on, or reduce us to the necessity of only blockading the place? what roads is the investing corps to follow, and what points must it occupy round the fortress? what cordon is it to form that merely a few troops may be wanted for the investiture, and the quarters be, however, properly connected together, supported by each other, and able to resist the enterprises of an active governor?

When it is wished to take a fortress by surprise, or by a sudden attack, great precautions are required, and considerable obstacles encountered; the principal of which are the difficulty of approaching and the secrecy to be indispensably observed, as without it the enterprise will miscarry; indeed, every circumstance concurs in preventing the assailants from gaining such precise information as they should possess. Besides, the cordon formed by the investing corps is far distant from the centre of the town, and the only roads to it, which the troops can follow, consist of walls to be climbed over or descended from: finally, any error committed in the estimation of the obstacles, and even a deficiency in the explanation of the direction in which the assailants are to advance, may put them at the mercy of the garrison.

All the details which, in a siege, ought to be reconnoitred subsequently to the opening of the trenches, require the application of fixed rules as well as regular proceedings, which allow the commander of the besieging army not to attend personally to those details; but his own particular attention is requisite with regard to the camp which the troops are to occupy. Besides, is it proper that the army should be enclosed by lines? for, the strength of the garrison, and the position of the enemy, may render them indispensable or useless, without speaking of the facility or difficulty with which they may be thrown up, according to the ground. Lastly, the number of the points of attack, as well as the nature of the approaches, should bear a relation to the strength of the army, and the number of troops that are required for the various operations connected with the siege.

The vicinity, or the approach of the enemy, may require that the principal army should cover the besieging troops, and intercept the convoys and succours of every kind which are sent to the garrison; in which case, the proper choice of positions, the movements to be performed, and the actions to be brought on, do not any longer depend upon considerations relative to the enemy alone, but are connected, likewise, with the besieging army, the garrison, and the relation which the fortress and the country have with each other. A siege frequently occasions a battle, the favourable result of which may, in some instances, be decided by the taking of the place; whilst, in other circumstances, we shall insure victory by giving up the siege, withdrawing our troops, abandoning our works and equipages, and allowing the besieged a temporary possession of this booty, which a glorious triumph on our side will soon compel them to surrender.

A frontier, protected by many fortresses, retards the operations of an invading army, or renders them more hazardous. Places connected with each other by waters, roads, or by the inaccessible crests of mountains and their counterforts, afford a considerable number of lines and positions, either parallel, perpendicular, or oblique to the frontier, the comprehensive properties of which should be carefully considered. At what point shall we break through the frontier, and in what direction? what extent of it shall we occupy? in what manner are we to secure our flanks and rear, as we advance into the enemy's territory? what are the fortresses to be besieged, and those to be only blockaded? in what order shall we proceed in order to diminish the resources of the enemy, augment those which the country affords us, and obtain possession of a greater number of roads and navigable courses of water?

Success renders every thing easy, whilst, in reverses, obstacles rise on obstacles; in this case, our attention must be incessantly directed not only to the enemy in front, but also to our flanks and rear; we are then frequently to traverse a country which is new and unknown to us, or, at least, to see it with other eyes than when we traversed it before. Difficulties increase, and our means diminish; it becomes more important and difficult to insure subsistence, and provide for all other necessities; every thing must be foreseen, even the smallest passage explored, and the most trifling accident valued; very little may favour our movements, or delay and perhaps entirely stop them, force us to fight contrary to our wishes, or afford us a favourable opportunity for attacking the enemy, raise the spirits of our army, or depress them.

To the difficulties which an unsuccessful army usually encounters, may be added those arising from unexpected circumstances; such as the population rising in arms against it; the inhabitants who become assassins, if not soldiers; the peasants flying with their cattle; the enemy ravaging the country, in order to starve the army; in short, the necessity for the army to traverse a desert, either natural or artificial, in the midst of swarms of light troops, and sometimes of those armed brigands who are always ready to join the conqueror, in order to share in the spoils of the vanquished.

Had an invading army, which is afterwards compelled to fall back, advanced beyond large rivers, or beyond chains of mountains, or should the frontier in its possession be covered by lines of fortresses, its retreat may terminate at those great barriers, as they will stop the pursuits of the enemy; but, if the country is open, what will be the limits of his progress? what position is the army to occupy in order to cover its own metropolis, prevent the enemy from advancing further, wait in safety for reinforcements, and then resume the offensive?

What the enemy has done, or should have done when his territory was invaded, points out to the invading army, now on the defensive, the observations it ought to make, and the measures which it must take; for, as it is in the same situation as the enemy was, the line of conduct which it should pursue ought to be the same also.

Sometimes hostilities continue during the winter, in which case, the rivers, streams, and canals, which are frozen, the deprivation of grass for the horses, the clothing and subsistence of the army, the particular precautions which the season renders necessary, the extraordinary fatigues, and the necessity of proceeding in the operations with celerity, influence the combinations of a commander, and oblige him to consider the configuration and resources of the country under other points of view.

Even supposing that the season is to suspend hostilities, the cantonning of the troops, and the establishing of the winter quarters, require the most extensive information respecting the configuration and resources of the country, as it is in these quarters that the army ought to refresh, and to repair its losses. Besides, however distant the enemy may be, and although chains of mountains may intervene between the two armies, yet surprise is to be apprehended; indeed, great examples have proved that a man of genius may surmount, in the execution of his plans, the difficulties arising from distance, as well as any other obstacles; in what manner, therefore, are the movements of the enemy to be watched, as is indispensably requisite? what chains of posts and reserves should be established? at what points shall such or such troops assemble in case of an attack? what are the means of communication, and the central position where the army is to form?

Lastly, it sometimes happens that two armies actually agree upon a suspension of hostilities, and only draw up a line to separate their quarters, instead of falling back to a distance from each other, and establishing themselves, as by a kind of tacit convention, in the hearts of the countries which they respectively possess; but, even in this case, the enemy should be watched, and particularly if he has not given sure pledges of his good faith. It is especially in settling the conditions of such an agreement, that a knowledge of the opposite countries, of their relations with the war, and of the strength and views of the enemy, is requisite; as the commander, who possesses the best information in that respect, may profit by his advantages, cramp his adversary, render the truce fatal to him, and place himself, on the contrary, in a rich country, which facilitates, and therefore favours, the future operations which he has in contemplation.

The various subjects of information which war in general, and the particular operations relative to it, require, have been explained in this article. But in what manner will the commander of the army, the minister at war, and the head of the state, become possessed of such an immense number of details? what eyes are to observe, and what hands are to collect, them? what known method, what certain means of observation and research, may guarantee their truth? In short, how can these details be brought together, reduced to a convenient compass, and so arranged, that a glance will suffice to embrace and combine them all? These matters shall now be investigated.

ARTICLE III.

On the sources in general from which the preceding subjects of information may be obtained, and particularly on Reconnoitrings.

Without considering the means that politics render excusable, and diplomacy authorizes, we shall investigate those which a military man may use.

Engineers, supplied with the necessary instruments, repair to different parts of the country, and connect its principal points by imaginary lines which they calculate, making such astronomical observations as the nature of their operations requires; whilst others inscribe within the large triangles, or triangles of the first order, which the former engineers have formed, smaller triangles, constituting those of the second order; and, guided by the numerous points already determined, they project on a plane the outline of the ground, and that of the objects which are on its surface; the precise situation of the various important points of the country being thus determined, drawing, and even painting lend their assistance to geometry, in order to form a map in which the objects are represented exactly as they appear in nature, although with smaller dimensions.

Such is the result of a survey performed with particular care and great precision; in short, of a survey which has all the perfection to be attained by means of geodesic and astronomical observations, combined with an accurate representation of the details of the ground. Government, the minister at war, and the commander of the army, may thus view the whole country in a map, the moderate size of which enables them to embrace it at a glance; and as this map speaks to their imagination as well as to their judgment, it answers the same purpose as a sight of the country itself, by giving them ideas, and guiding them in the formation of their combinations and projects.

In order to complete the information thus obtained, written memoirs should be subjoined, which contain observations carefully made respecting the influence of the climate, the nature of the soil, the state of the roads, the extent of the population, the dispositions of the inhabitants, and the resources of the country; in short, respecting every particular which cannot be expressed in a drawing.

But surveys and memoirs of this kind require much art, time, and expence; and particularly, that we should be masters of the country where the operation is carried on; as, without these conditions, the results will be imperfect, and only approximation obtained; mere sketches must supply the place of accurate drawings, and descriptions become simple reconnoitrings.

Besides, the expence attending precise descriptions may be such as to exceed the means of a poor country; and nations, which have not yet attained a high state of civilization, do not possess the degree of knowledge which they require; nay, even in states, where arts have made the greatest progress, stronger interests, or more pressing necessities, have diverted the attention of government from these purposes, required another use of the funds which might have been appropriated to them, or prevented the men qualified for such operations from taking them under their direction.

Although a state may be tranquil, and the world at peace, yet government, if it be wise, will anticipate war, and foresee the return of those periodical fevers which come upon nations and hurry them to arms; it will lay out the defensive system of its frontier, and prepare in silence those establishments which the offensive operations it may carry on at a future time will require. Peace favours regular undertakings of this kind, but its presumed duration, and political or economical motives, may force government to have recourse to reconnoitrings, and these will frequently be sufficient. The frontier was previously described, wherefore it is only requisite that some parts of the territory, which are less known, should be added to the description, and such changes observed in other parts, as were effected by nature or by men; or, perhaps, that the ground should be considered under a particular point of view, on account of some intended works.

Common interests with our ally will allow us to make the same operations during peace in his country; but it is only in time of war that we may perform them on the territory of our natural enemy. Besides, the researches and observations of a military foreigner raise suspicion and alarm among several nations where the number and repartition of the troops, the works belonging to fortresses, and all military details are considered as secrets which the state alone should know; therefore let our government penetrate into them by using those means which policy approves. With regard to a military man, he surveys such countries as a traveller, and satisfies himself with observing all the particulars which even the strictest distrust cannot conceal from any person. Like a naturalist, an agriculturist, or a man simply curious, he examines the general configuration of the country, the nature of the roads, their directions, the situations of the towns, the details relative to agriculture and commerce, the manufactories, in a word, the statistics of the country. Finally, he studies, on the spots where battles were fought, those great lessons which a comparison of the manœuvres of the victor, with the faults of the vanquished, puts it in his power to learn. Travels of this kind have considerably improved the military art in several nations, and the applications which officers may make in time of war, of the knowledge they have acquired by that means, are very numerous. Who is not aware of the lively interest with which the commander of an army questions any person who has travelled over the theatre of war? Indeed, nothing is equal to the advantage of having seen a country, and no erudition adequate to the short and precise answers of a military man who has seen it. Governments know this truth, wherefore they favour in time of peace the excursions of officers in the adjacent countries; and war, like the sciences and fine arts, has its travellers.

Such are the reconnoitrings which peace admits; but the approach of war limits their object as well as the ground upon which they are to be made, the length of time that may be applied to them, and the degree of perfection which they can have; it is particularly important in this case that the insufficient information which government may possess respecting the extreme frontier, the lines of departure, operations, and communications, the debouchés, the inroads, and the means of diversions, should be instantly completed, in order that not even a single moment may be lost in forming the plans of campaign, assembling the troops, ordering the necessary preparations, and beginning the works which are suitable to the present circumstances.

War is declared, and the officer, escorted by detachments or by parties, already penetrates into the enemy's territory, with his sword and pencil in his hand; he observes, and is at the same time ready to fight, using all the means which war authorizes, in order to procure the information it requires.

The operations commence, and until the campaign is at an end, the immediate or more distant wants of the army will render a great number of reconnoitrings requisite. The staff-officers and the engineers, at the heads of the columns, in the vanguards, with the parties, the detached corps, the troops intended to explore the country, those which are to flank the various sub-divisions of the army, and most frequently under the immediate protection of escorts, follow the movements of the enemy, study the ground which he occupies, and collect all the particulars relative to marches, encampments, actions, sieges, quarters, lines of neutrality, and military works of every description; taking into consideration the peculiar situation of the army, according as it is advancing, stationary, or retreating; in the mean time, and until the army falls back, engineers-geographers* survey and describe, with greater precision than the former officers, the ground which it has passed over, the camps, positions, and fields of battles, and collect very useful materials applicable either to retreats or to a renewal of offensive operations, as well as to the history of the present war, and the combinations which future campaigns may require.

It is also during prosperity that the staff-officers and the engineers may reconnoitre the relations which the country, the fortresses taken from the enemy, and the positions, either in their natural state or fortified, have with the operations to be carried on in case the army, which may meet alternately with success and misfortunes, should be compelled to defend the ground it has conquered. This the proper time, likewise, for laying before-hand, after preliminary reconnoitrings, the plans adapted to the various circumstances which may occur, regulating the camps and positions to be occasionally occupied, establishing the têtes-de-pont, the military roads, and preparing those extensive inundations, of which Holland and Flanders afford examples, by means of which the fortresses may be connected on a sudden as well as the positions, and the flanks or the front of a considerable retreating army, be covered.

Such are the modifications which peace or war, the presence or the absence of an enemy, may introduce into military reconnoitrings.

The staff-officers, the engineers, and the engineers-geographers, are not the only persons concerned in these reconnoitrings, as the officers of all arms, who are station-ed at the out posts, or employed in operations relative to the petty-war, and those who accompany patroles, are to follow the enemy step by step, and to transmit incessantly information respecting the changes which they perceive in the number and position of the troops opposite them ; in a word, every individual belonging to the army, who is so situated as to be able to observe the enemy, should observe him.

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* The engineers-geographers in France are particularly employed in surveys and other operations relative to topography.

I shall not enter into any particulars with respect to the reconnoitrings which general officers make either in the field or in time of peace ; these serve in verifying, connecting, and reducing the others, as well as in combining the elements which they afford ; and it is incumbent upon our leaders only, to acquaint us with the secret of their art ; admitting that this secret does not entirely reside in the *coup d'œil* which is the fruit of experience, or in those still more sublime qualifications which nature alone gives.

ARTICLE IV.

On Instructions.

THE circumstances we have noticed, besides many others which were not mentioned, some particular purposes, secret views, and, finally, time, which it is very important to consider in war, limit in a great number of cases the extent and precision which reconnoitrings may have.

Instructions are sometimes subjoined to the orders which an officer receives ; they elucidate those orders, and enable him to seize the spirit of them, tracing out at the same time the limits of his work, and the method which he is to pursue in accomplishing it.

Even supposing that these instructions may not remove all doubts, yet they will be very useful; but the urgency of the operations, and the secrecy to be observed, do not always allow an officer to be supplied with detailed instructions, as it most frequently happens, on the contrary, that an order, which was given to him with the rapidity of an arrow, admits of no questions to the general who gave it, although the latter might be willing to answer them. Then, what must an officer do in such circumstances? He ought to conjecture what is required of him from his knowledge of the state of things, the expressions and tone of voice of the general, as well as from other indices, and to execute with every possible celerity the order he has received: indeed, in reconnoitrings which are made in the field, nothing perhaps requires so much intelligence, military knowledge, and particular fitness for the operation, as the art of divining a general, understanding his orders from half a word, estimating the supposed time which is granted for their execution, perceiving at a glance what can be done, and seizing the most important parts of the general purpose of the reconnoitring which is to be made, without attending to useless details, or aiming at an unseasonable perfection in the results, as is but too frequently the case.

It ought to be added, that it is not an officer's business to decide whether the work which he is ordered to perform is requisite or useless; nor to extend it beyond the limits that have been prescribed to him, and embrace objects which in his opinion were overlooked; in short, he should not suffer himself to be inconsiderately hurried on by the impulse of his imagination, and thus exposed to the sad displeasure of having done harm by taking steps of his own, which he thought would render him highly useful. Therefore, his knowledge ought not to serve him in amending or rectifying the instructions of his general, but in understanding them, and seizing the spirit of them without being a slave to the letter.

An officer, whose conception is slow, should be diffident of himself; indeed he may prove useful in operations which require more care than quickness, and greater judgment than perspicacity; but in war, all will be lost through his tardiness, if he is unseasonably reflecting, when time, the general, and the enemy, require that a reconnoitring should be made at a glance; the favorable moment for acting will be over before he has done deliberating.

If, on the contrary, his genius prompts him to this kind of service, and should he wish that even the shortest instructions, an order given in haste, a word, a gesture, or a sign, may always sufficiently inform and direct him, let him study his general, and observe that striking correspondence which we perceive, particularly in men who have charge of very important matters, between their thoughts and the exterior signs which manifest them; nothing is more disagreeable to men of this description than the necessity of explaining things fully; unconnected words slip from their mouth, and they do not appear to pass distinctly from one subject to another; the orders they give, and their successive recommendations, seem, at first sight, to belong to different combinations, but if we approach these orders and recommendations to each other, and compare them with the objects that strike our eyes, they will unite together, and actually guide us.

The talent of understanding orders and instructions given in the manner above stated, is the first which the co-operators of the head of the state should have, as well as those of the war-minister and general; but an ordinary man will not have it, and particularly if there be no mutual confidence between him and his employer; for such confidence may supply the place of talent to a certain degree, and even the men who actually possess the latter will derive from the former more comprehensive means of rendering themselves useful; intimacy still augments these means. What will not Polybius do for his friend Scipio?

ARTICLE V.

On the Materials which may serve in forming the Outlines of Military Reconnoitrings.

SHOULD war be carried on in an unknown country, against a savage people who are strangers to arts and have no relation with civilized nations, the officers ordered to reconnoitre such country would not be supplied with any other materials but those which they might derive from their own observations, and from questioning the inhabitants; happy indeed should they frequently deem themselves, at not being deceived by the tales of some romantic travellers.

But a multiplicity of useful materials can be found in almost all the countries which most commonly become the theatre of war; a great number of determined points, some from their latitude and longitude, and others by means of more or less precise geodesic operations, gives the general outlines of the territory; wherefore, it is only requisite to ascertain their accuracy, fill up the vacancies, and connect the boundaries with those parts of our own country which are the nearest to them; these outlines constitute the general maps, in which the courses of water, and the directions of the principal chains of mountains, are almost always expressed;

besides, a vast quantity of special maps, more or less detailed, affords topographical sketches, which are, therefore, more or less finished, of many parts of the country, if not of the whole territory; such are the maps of provinces, and those of civil, military, and ecclesiastical divisions; also, the maps relative to the general registering of lands, some particular spots, the assessments on landed property, the forests, and to the roads and canals; such are, likewise, the maps and plans of the battles fought in the country, and of the marches of the armies; as well as those which represent the encampments, fortresses, and lines, their environs and attacks, or which are connected with any other military establishment. Other materials, such as the writings of geographers, the annals of past wars, those of the country, the registers of lands, the collections of statistics, even the accounts of travellers, elucidated by each other, and especially the memoirs relative to former reconnoitrings in the same country, may supply an officer with a rough sketch of the descriptive memoirs which he is to write, and almost with the outline of them.

But how greatly embarrassed officers would be if they were to search for these documents, and to investigate their accuracy! what amazing expence and extreme labour would be requisite, in order to collect them privately! Besides, what would become of these private collections in the hands of the families which possess them, as children seldom inherit the talents and inclination of their father, and frequently do not follow the same profession!

The French government foresaw these difficulties a long while ago; wherefore, it has been collecting in the *Depôt de la Guerre*, ever since that time, all the important documents connected with military operations in general; and in the *Depôt des Fortifications*, the immense details, particularly relative to the site, construction, and means of defence of the French and other fortresses. These depôts derive their origin from that famous age during which a sovereign, always ready to favor great and useful undertakings, and assisted by an able minister, founded so many military institutions in France, which render the success and glory of the French armies less dependent upon the chance of fortune; and the intended purposes of both establishments were, to collect all the most valuable maps, plans, drawings, memoirs, and works, relative to sieges and other military operations; to prevent their being lost, and the state being thus obliged not only to make the same collection again, but also to incur a double expence in procuring the same results. Finally, it was in contemplation, to secure to France alone the possession of the principal documents collected in these depôts, without any rival country having it in its power to use against the French the product of their own labour.

In order to obtain a greater quantity of materials applicable to war, and to bring the whole to a common centre, the *Depôt de la Guerre* and the *Depôt des Fortifications* incessantly correspond with each other, and with the establishments analogous to them, which have been formed for the other branches of the public service. The materials of every description are examined and elaborated in these depôts, where, after a severe criticism has appreciated them at their just value, they are arranged according to their respective destination, and consistently with an invariable method; it is in these depôts, likewise, that a work, the tions and analogies may furnish him with general ideas respecting the configuration of the ground, the laws of nature, and the means which industry affords; nay, even supposing that an officer is unwilling or incapable of acquiring these notions, yet, that kind of *coup d'œil* which arises from practice, and that acute discernment which the mere habit of seeing and observing gives, without scarcely any exertions, will serve him in estimating the accuracy of the maps he has collected; similar, in this respect, to the huntsman of the Alps and the Pyrenees, who wanders in those mountains and never loses his way; or to an artist, whose exquisite feeling enables him to know an antique statue from the most resembling and perfect copy.

If an officer possess that instinct, it will guide him, without any exertions, and never deceive him: neither science nor study is requisite in order to acquire it. Let him frequently observe from the tops of mountains, or from other elevated points, the directions of the heights, waters, and roads, as well as the situations of the towns, villages, and hamlets, in short, of every object placed on the surface of the ground: let him compare these objects at the same time, from the same spots, with their projections and figures traced on maps which have been executed with care and accuracy, and he will soon perceive a general order amidst this apparent confusion; he will be struck with the symmetry that distinguishes the works of man, and with the irregularity which those of nature present; but he will also be soon convinced that nature herself is subject to laws, even in her aberrations, and although he may not be acquainted with those laws, yet he will observe that she has her peculiar forms, features, and figure.

These characteristics of nature are particularly remarkable and striking in the courses of water; their contours have inflexions solely their own; the most ably-conducted pencil, and the best imitation, cannot represent in a map, which is drawn from imagination or recollection, that continuity of grace and variety which rivers, the innumerable streams which fall into them, lakes, and even sea-coasts, exhibit in their numberless bendings, wherever insuperable obstacles, some overturnings of ground, and other accidents which may form an exception, have not opposed the oscillations of the waters, as well as their slow and progressive action along the banks which they wash.

This deviation from nature, in the description of waters, is especially sensible, when, the outlines only being represented, we compare an accurate map with one which was drawn from fancy; as, even supposing that the eminent talent of the draftman may have enabled him to divine nature in some degree, yet he could not preserve that measure and that economy which we observe even in her irregularities; indeed, draftmen almost always make her more rich than she is, as they cannot faithfully imitate her beauty.

Although the laws which the solid parts of the globe follow, with respect to their forms and directions, are less simple and regular than those relative to waters, yet their general configuration has features peculiar to them; for instance, the eminences on each side of a valley frequently make corresponding, parallel, and alternate sinuosities, as if a river, which runs within it, had formerly filled up the whole valley, the bottom of which it now only occupies; even the whole masses which mountains form, and the several parts of them, their rents, defiles, depressions, and anfractuosities, offer numberless resemblances which similar circumstances produce in places distant from each other, and separated by rivers, lakes, and even by the sea. In short, all those details, which we do not conceive before seeing them, have a peculiar character that can only be seized upon the spot, and our imagination alone alters instead of imitating them; but, upon this point, experience will also teach us how to distinguish, in a seducing map, the circumstances of the ground that are accurately represented, from those which are not; indeed, a draftman vainly attempts to heap, like the giants, Pelion upon Ossa; these accumulated mountains and this chaos, which other eyes may consider with rapture, only appear, to an experienced officer, as the performance of a draftman who wishes to please at the expence of truth.

The roads, canals, and communications of every description, as well as the situations of the towns, villages, and establishments, either connected with them or insulated in the midst of woods and in the gorges of mountains for the sake of convenience, have necessary relations with the waters, soil, and with nature and its productions, which are the same at all places, and may be easily discerned and seized from experience, observations, and travels.

A traveller, who is incessantly comparing maps with the ground which they represent, will find out, in an incorrect map, I will not say the faults which the inhabitants have committed in choosing such and such positions in preference to others, but those which they surely could not commit, and inconsistencies that testify the ignorance, carelessness, or caprice of the author; in this manner, he detects from the outlines of a map, that the objects which they encompass are not accurately represented, and reciprocally; likewise, if he looks at the description of a canal, it will strike him that its direction is defective, or that important running and stagnant waters have been omitted, or, in fine, that the sinuosities of the ground which the canal traverses, are not such as the draftman has represented them: in this manner, too, a comparison of the roads with the ground will serve him in ascertaining how far he may depend upon the exactness of their directions, and the positions of the places through which they pass; nay, he may frequently conclude, from the places and roads indicated, that some intermediary roads, which actually exist, have been omitted in the map, and find, within a near approximation, their directions and positions, as well as the situations of the paths, bridges, ferries, fords, and other means of passage.

Such are the advantages which may be derived from the mere habit of seeing, observing, and comparing a ground with the map of it; and this kind of practice, even supposing it independent of theory, is a surer guide than speculative science alone; but the reader will soon see what more powerful means theoretical instruction, united with practice, affords to those who possess it.

Although memoirs, tables, and other materials of the same description, whether printed or manuscript, are more difficult to appreciate than the preceding documents, yet reflection, and the habit of consulting them, may help an officer in estimating their merits: those which belonged to local administrations generally deserve his confidence more than any other, and especially if they served as bases to the operations of these administrations. Let him endeavour to learn the names of the authors, and whatever relates to them personally, such as their rank, their profession, and their reputation. A writer does not acquire a renown for accuracy and veracity without deserving it, especially when he treats of his own country, and of objects which every inhabitant has under his eyes. The justice which is done to his dispositions and probity gives an additional weight to these first testimonies; the situation in which he was when he wrote his work will show, as well as his connections and employment, if he had the means of making correct observations, or, at least, of consulting accurate materials. His profession also offers other indices: for example, we may expect from a military man valuable details relative to war, and from an administrator, certain documents upon the resources of the country, provided however these men confine themselves to matters which they fully understand, as is not always the case. In short, the general tone of the work, the simplicity of the author in expressing himself, and the particular care he takes, not only to justify the facts that are advanced, but also to indicate the sources from which the documents he furnishes are drawn, ought to excite confidence; whilst a contrary tone and opposite qualities should remove it.

But, whatever may be the degree of confidence which materials appear to deserve, time may have modified the places and circumstances. Routine, a bad administration, the difficulty of making innovations, and the deep root which abuses may have taken, commonly cause old or defective documents to be used by the public authorities, as the basis of their operations in regulating the repartition of the men to be drafted for the militia, of the contributions and statute work, in short, of all the charges laid upon the inhabitants. Culture may change in a country, commerce diminish or improve, and industry be active or languishing. The political institutions, national spirit, and even the manners, which time alone alters only at a slow pace, receive sudden and striking modifications from a great event; a general and continual movement animates nature; the action of the waters some subterraneous fire, and the influences of the atmosphere, occasion alterations in the soil, change after ten years the aspect of the mountains and sea coasts, deface whole grounds, or conquer from the sea a new soil. Thus, even the materials, which are the most entitled to credit, do not dispense with fresh observations when they are old; and, with regard to incomplete materials, they undoubtedly require more precise observations, if time permits to make them.

We shall now examine what assistance the arts and sciences offer to an observer who calls them to his aid.

ARTICLE VI.

On the Instruments and approximate Processes which may be used in Military Reconnoitrings, for forming the principal Triangles, determining the Positions of Places, and taking Distances and Altitudes.

FROM the most rigorous observations, to a simple glance thrown over a country, a series of approximations may be conceived, the terms of which are determined according to time and circumstances. We shall now examine what use may be made, in certain cases, of some expeditious means, and how far imperfection in the instruments and the methods employed may be overlooked, in order to conform to the shortness of time, and satisfy necessities which admit of no delay.

The *Memorial Topographique et Militaire* contains detailed instructions upon geodesic operations, which leave nothing to be wished for.* They embrace, unfold, and rightly recommend all the precautions which regular surveys require; and any officer, who is able to attend to those precautions, will also know what attentions mere reconnoitrings allow him to neglect in measuring angles, bases, and in the accessory operations. He will treat the triangles of the first order as he would those of the second in regular surveys, and employ smaller instruments; he will, likewise, take objects from a greater distance, and use graphical constructions instead of calculations; provided, however, he is accustomed to these constructions, as, without it, the errors committed in the survey would be augmented by those arising from the use of the ruler and compasses.

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* The instructions, to which the author alludes, are those contained in the first volume of this treatise.

The *Memorial Topographique et Militaire* contains also, in the third number, a notice upon Hadley's sextant, the principle of its construction, and the inconveniences and advantages arising from the use of it; as this memorial expresses in a few words, Tobias Mayer altered the sextant to a whole circle which was afterwards perfected by Borda, like every other instrument, usually employed in geodesic operations, which this illustrious man undertook to improve.

This essay scarcely admits of a detailed description of Borda's reflecting circle,* and we shall only observe that its construction is founded upon the following optical principle, that a ray, which is reflected, makes in its first and new directions equal angles with the surface upon which it falls; or, which amounts to the same thing, with a perpendicular to this surface at the point where the ray meets it. This instrument carries an index with a telescope, besides a common index; a mirror, adapted to the latter, follows its movements, and reflects one of the objects to be compared together, in another mirror posited in the direction of the telescope, but which is transparent in a place that allows the observer to perceive the second object to which the telescope was first directed. The component parts of the reflecting circle are so disposed, that, when the images of two observed objects appear exactly over each other, the common index has described, upon the graduated limb of the instrument, an angle equal to half that which the visual rays directed to the objects make at the point where the eye of the observer is placed; wherefore, the observer has only to ascertain the instant at which the objects coincide in the aforesaid manner.

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* A minute description of Borda's reflecting circle, with appropriated figures, is inserted in the first volume of this Treatise.

One of the advantages of this circle is, therefore, that of giving at once the directions of two objects which can only be determined successively with other instruments. Besides, it does not require, like them, that one of the directions should be verified before and after taking the other, which renders the observations longer, and gives rise to various inconveniences.

Contrary to the sextant, Borda's circle gives multiple angles like the repeating circle, and thus substitutes for one positive or negative error, which would otherwise remain in its full extent, the very small difference occasioned by errors in opposite directions, which, therefore, materially compensate and may even destroy each other entirely, if we choose.* Lastly, we are indebted to Borda alone for the advantage of being able to observe with the circle, without being compelled to turn it, or change our position, any object situated either to the right or left of the station : in a word, his circle is so superior to the sextant, that the respective accuracy of these two instruments bears no comparison, when their radii are equal ; and a circle, the radius of which is much smaller than that of a sextant, will afford the same precision as this last.

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* See the description of the repeating circle, in the first part of this Treatise, Vol. I.

Borda's reflecting circle is sufficient for determining the secondary triangles in a rigorous survey ; and it may be used in reconnoitrings, for verifying or completing those of the first order, in maps drawn from surveys in which extreme precision was not aimed at.

The dispositions and concert which a series of connected triangles require, are prequently prevented by the shortness of time and the nature of the country, some peculiar circumstances which intervene, and by the unavoidable dispersion of the observers ; while each of them, although he is alone and far distant from the others, may determine, by means of astronomical observations, the position of the places which he only traverses, or where he resides for some time. Borda's circle is particularly useful for this purpose, and common observations will not require a radius greater than three or four inches ; an artificial horizon, which may be carried with as much ease as the instrument itself, is adapted to it, and serves in taking altitudes and zenith distances.

Instrument makers construct circles still smaller than the preceding, which have the form and size of a common watch, and may therefore be conveniently carried in the pocket. Such ones are particularly useful to engineers, or other officers, who travel by order of government in a foreign country little known, the maps of which are either incomplete, with regard to certain parts, or affected with great errors.

The construction of Borda's Circle allows the observer to hold it in his hand during the observation, and he takes the angle with great facility, in whatever position he may be; it was tried to use this circle in areostatic machines, and the experiment suggested ideas which tend to multiply the results of a single measure, and to furnish the means of accomplishing, almost at a glance, what cannot be done with other instruments without a series of operations.

As the continual balancings of a vessel, in which observations are made, require that the instrument used for that purpose should give two directions at once, this condition appeared still more requisite in areostatic machines, wherefore the circle was adopted; besides, the elevation of the observer rendered it necessary that the observed angles should be reduced to the horizon; and, on account of the movements of the machine, that the elements of this reduction should be determined at the same time as the directions to the points of view; in a word, three angles were to be taken at once, namely, the principal angle, and those which its sides respectively form with the horizon; this was effected by adding to the circle a *fausse equerre*,* two plumb-lines, two new limbs, and a kind of trigger. This apparatus may be still improved, and some engineers are exerting themselves in improving it; indeed, such an undertaking fully deserves their attention, as the result may furnish the means of performing rapidly Geodesic operations, and reconnoitrings in particular.

The experiments which served in determining the

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* The French call *fausse equerre* an instrument composed of two rulers, which are joined together, and form an oblique angle.

Translator.

the additions to be made to the Reflecting Circle, were also intended to show how far areostatic machines may be serviceable in surveys; and it was found that, on account of their mobility, they should not be used when great precision is required; but it was ascertained, on the other hand, that they may be employed to advantage in forming secondary triangles, filling up outlines, and in reconnoitrings performed by the eye alone.

In fact, it may be easily conceived that the use of these machines, in Geodesic operations, makes all the obstacles on the surface of the ground disappear, which limit, impede, and slacken the observations; and also, that it is very advantageous, in representing the ground, to view all the asperities of it from a height, which, instead of altering its various forms, tints, and colours, present them, on the contrary, according to their general effect; without speaking of the great advantage, particularly in a mountainous country, of discovering an immense space of ground at a glance, and seeing nature as it is required to represent it.

The use of areostatic machines may be applied, likewise, to other purposes, and if *Meunier* and *Conté* have not yet sufficiently improved them, in order that the inconveniency of conveying them with an army may be compensated by great advantages derived from them for military operations, at least, what was already done evinces a proof that further improvements may be contrived; it is undoubtedly not impossible to simplify still more the apparatus of these machines, and to render the manœuvres relative to them sufficiently easy that their utility, on a day of action, will overbalance every inconveniency.

Even at this time, their construction, the means of conveying them, the materials which they consume, and the apparatus requisite for them, do not occasion larger expence or greater difficulty than the fabrication, conveyance, use, and consumption of the machines of war employed in sieges; nothing prevents advantages being already derived from them, in attacking places, and particularly in defending extensive fortresses: in these slow and methodical military operations, the fields of battle are known beforehand, and always limited; it is easy to conceive how useful areostatic machines may be for reconnoitring the works and trenches, the progress of the attacks, and the disposition of the artillery and troops; also, for being informed that sallies are preparing; and, perhaps, for corresponding with distant armies which keep the field, since experiments have proved that these machines may furnish methods of holding a telegraphic correspondence, either in themselves, or by means of the apparatus they may carry.

It is in vain to object that our enemies will use the same means, and thus re-establish the equilibrium; for, of what import is this to us, if we do not remain stationary while they are exerting themselves in discovering those means, and if we improve a method which they only attempt to imitate?

Repeating circles, reflecting circles, and areostatic machines, are not the only means of observation which may be employed in extensive operations.

The conveniency of chronometers for estimating the longitude is such, that geography ought, perhaps, to borrow this ingenious machine from navigation.

Other purposes may interest military geography in the perfecting of the instruments intended to measure time, and the reader will soon be shown the use which may be continually made of them in taking the details of a country. But, in order to confine ourselves at present to the formation of the outlines, we shall only say that the measure of time is also one of the elements of a simple and ingenious method of determining them, which is, perhaps, the most expeditious that can be employed.

Before we explain this method, we shall first observe that the velocity of light is not infinite; it requires more than eight minutes to come from the sun, and several years from the stars; but it passes over 192623 English miles per second, and the duration of its vibration cannot be estimated when it proceeds from an object within the circle of the terrestrial horizon.

It is not so with sound; its velocity is very limited; observations and calculation have given different results respecting the space which it passes over in a second, but, according to experiments, this space is about 1106.508 feet. By a singular property, which can scarcely be accounted for, sound, whether loud or low, grave or acute, and whether it can be appreciated or not, passes over equal spaces in an equal time; in fair and rainy weather, and whatever may be the elevation of the sonorous body; in short, in whatever direction the air may be first struck, the wind alone will modify the velocity of sound, which increases or diminishes about thirty-three feet in a common wind, and ninety-eight feet in hurricanes. Nay, sound is so much accelerated or retarded only when it follows a direction which is nearly the same as that of the wind, or contrary to it; for, should these directions cut each other almost at right angles, the wind will scarcely affect the velocity of sound.

These properties of light and sound have suggested the idea of applying them to the measuring of distances; for example, if a gun, or any other piece of ordnance, be fired, and we see the flash from the place where we stand, the distance of the gun from the place may evidently be ascertained by counting on a clock or a watch the number of seconds elapsed between the flash and the report, and multiplying it by 1106.508 feet, plus or minus the modification occasioned by the wind, if it should be necessary to take it into the account.

This method is undoubtedly subject to errors, but the approximation it gives is very frequently sufficient for military purposes, and we have at hand, in fortresses and camps, the means which it requires; besides, the application of these means is extremely easy, and by combining the method with observations of another kind, it will incessantly tend to perfection; the errors and the discordances in the observations will gradually diminish, and disappear at last; wherefore, geography may derive new resources from this expedient, and from the remarkable property which it possesses of giving immediately the sides of triangles, without it being requisite that the angles should be measured.*

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* The experiments made in 1738, in the environs of Paris, by M. M. Cassini, Maraldi, de la Caille, and which M. M. Bouguer and De la Condamine repeated in Peru at about 546.8 English yards above the level of the sea, also give 1106.508 English feet for the velocity of sound per second.

Those which were made in England and Italy give 1141.686 and 1148.082 English feet. Some learned men, such as Doctor Young, adopt the number 1130.172 English feet as a mean; but the extreme care with which the French Academicians attended to their experiments, the various stations where they performed them, the considerable distances between several of those stations, and the coincidence in the results, although they were obtained in different climates, and in situations differently elevated above the sea, in short, every circumstance leads us to prefer the observations of the aforesaid Academicians to the others.

We are justified in concluding from all the results, that night or day, a calm or a rainy weather, occasion no difference in the velocity of sound; and that it is the same, whatever may be the direction of

ARTICLE VII.

Continuation of the same subject.

THE positions of the principal places of the country to be reconnoitred being determined by astronomical and geodesic operations, these places, as well as the lines which connect them, are traced on a paper, and remitted to the officer who has charge of the reconnoitring; wherefore, it only remains to inscribe other triangles within the former, so as to obtain numerous points which become as many guides in representing the ground.

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spect to points, lines, and plans of comparison, are perceptible only when the intervals between them can be very easily distinguished, either in all points of view, or in some that are determined; wherefore, the signs which may be used in a telegraphic system, as well as the variations applicable to it, or to the elements of it, are limited by the distances, and by the number of positions in which it must present itself; besides, this system resolves itself into a line or a point, similarly to each of its elements.

This being premised, if we suppose that a vertical plane, upon which any number of lines are traced, is perpendicular to a visual ray drawn to it, and moves round a vertical axis while the eye of the Observer retains its position, all these lines will approach each other, and all the figures will change their form, as the plane is advancing; in such a manner, that they will resolve themselves into one single line, when the plane and the visual ray are in the same direction. It follows from this circumstance, that, if a telegraph is to present itself in different positions, and to be understood from all the points of the horizon when placed in the centre of a besieged fortress, for instance, such solids only as spheres, cones, and cylinders should be employed, and they should be united together in such a manner as to present the same appearances in all points of view; or, if the signs are situated in the same plane, the whole system ought to move round a vertical axis, and to make, for each sign, one or several revolutions with a greater or less degree of slowness according to circumstances, and the presumed distance of the observer.

It is scarcely possible to commit any material error in taking a moderate extent of ground, where many directions are already given; at all events, the facility with which the observer may return to the point whence he set off, enables him to prove his work frequently; besides, as the distances from the stations to the objects are short, the inflection of the visual rays in the air is small, and the errors from refraction, which increase as

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It has been already said, that an object, which is seen from a distance, appears smaller than it is, and this apparent diminution is simply proportional to the distance; but distances also change the figures of the objects, weaken the colours, blend and deface the tints, and this effect increases as the squares of the distances, as will be demonstrated in a subsequent note; this being, in truth, the case with the planes on which the objects are apparently projected, regarding them as sections (of a solid) at different distances from its vertex (the eye;) depending, however, on the nature and modifications either of the beds of air in which the objects stand, or of those which the luminous rays, emanating from them, are to traverse in order to reach the eye of the observer.

Lastly, the light of the Sun traces upon the objects a line, either straight or curved, according to the nature of their surfaces, which separates the enlightened part from that in the shade; these phases change the figures of the objects, and give them appearances which vary as the position of the luminous body, and that of the eye of the observer.

These observations, which may be easily verified, are sufficient for guiding an officer in the choice of the objects which should be used, according to the ground, the distances, and the telescopes at hand, &c.; and also, for enabling him to determine in what manner these objects ought to be united together, the positions that should be given to them, &c.

It is not useless to remark, that luminous bodies, port-fires, rockets, and other fire works, or guns fired in numbers, and at intervals previously determined, form, during the night, telegraphs so much better, as the light and sound strike the eyes and ears from a great distance in the obscurity and silence.

the distances, require no correction. Lastly, such instruments as are used generally dispense with reducing the observed angles to their corresponding horizontal angles, and should a point of observation render this reduction indispensable, that point may be avoided.

Therefore, it is only requisite, in taking the particulars of a country, to describe on paper triangles similar to those which we observe on the ground.

Without investigating the easy theory of this construction, or explaining the common use of the plane-table and the compass, I shall acquaint the reader that the former instrument is better adapted to regular surveys than the latter, and that the precision it gives may be more safely relied upon; but the compass is more expeditious, and, as it may be used in all places, positions, and even on horseback, it is commonly employed in reconnoitrings.

The number of the objects, and that of the positions which may be given to them, being determined by the construction of the telegraph, an easy calculation will indicate all the combinations which can be made; and it is only requisite, that the term beyond which they would become too much complicated, should not be exceeded; but in practice, these combinations must be arranged, and telegraphic tables made; which may be easily done by representing each sign by a letter, and comparing them two by two, three by three, &c. (See the various works in which the elements of arithmetic and algebra are explained.)

After arranging the combinations and making the tables, such or such values must be affixed to each sign, or combination of signs, and these values are, first, the most usual phrases relative to the particular purpose which the telegraph is intended to answer; with respect to the eventual phrases, a certain number of simple signs may be applied to expressing the cases of nouns, and the tenses of verbs, the punctuation, and the other elements of the phrase, while the remainder of the simple or combined signs will indicate the syllables, or the letters of the words.

I shall observe, likewise, that in this last branch of service, time commands every thing; we cannot conveniently use different instruments or divide the work; besides, we are subject to unforeseen wants, and must have numerous resources at hand, without being, however, encumbered on that account; therefore, an officer who orders instruments for his own use, should have them constructed in such a manner as to be fit for all purposes; they must serve him in taking angles situated in planes either parallel or inclined to the horizon; in determining the distances of inaccessible points that are not included in the outlines with which he is supplied, and in observing relative or absolute heights, which it is frequently necessary, and always useful, to write down in a map. Lastly, he should not be compelled to make many stations, or subject to such attentions, in choosing those which he fixes upon, as confine or slacken his work.

The instruments generally used are far from uniting these properties.

A common plane-table, for example, is troublesome and inconvenient to carry; but this defect may be easily rectified by diminishing the dimensions of the table, and making it into a kind of box, or case, in which all the requisite implements for the survey, and the drawing of it, may be enclosed. The number, weight, and dimensions of these implements being reduced to what is strictly necessary, a graduated staff, shod at the foot with a pointed cap of iron, may serve in supporting the table, and in taking measures on the ground.

Besides, this plane-table affords but little scope in the choice of stations, and does not allow us to observe objects which are elevated or depressed by a certain quantity, with respect to the plane of the horizon; indeed, the index being fixed in any direction, the telescope may move in a vertical plane along an arc of some degrees; wherefore, we may project on the plan every object which the visual ray meets in this motion; but the small elevation of the telescope above the table, and the distance of the centre of motion from the edge of the frame, leave only a little field for the visual ray, since this edge stops and confines it.

The field of observation is still more limited, when, instead of a telescope, a common index with sights is used; for the visual ray must graze the wires, and it cannot be raised or depressed without passing soon above or below them; even supposing the index to be so disposed, that this ray shall not meet the edge of the table before. Therefore, if an officer orders a common index to be made, he ought to direct the maker, in order to be less confined in the choice of his stations, to raise the sights as much as possible above the ruler; or, in case there should be a telescope adapted to the index, to elevate the axis of rotation of the former in the same manner. He may recommend, likewise, with respect to a common index, that, instead of the sights being fixed to the extremities of the ruler, they should be placed at those of a rod of metal raised and supported as a telescope, and which moves in a vertical plane, similarly to it.

But these modifications should not exceed proper bounds, as without it the index will become unsteady, inconvenient, and will take too much room in the aforesaid box; a good workman will remove these difficulties, by making the ruler wider, and causing it to fold upon hinges on the mounting of the telescope, or of the rod of metal before mentioned; nay, the disposition of the telescope and moveable index may be such as to allow them to be separated at pleasure from the ruler, or to move upon it in such a manner, that they may be brought, in every position, to the edge of the table. A triangle, or any limb, fixed perpendicularly upon the ruler, would answer the same purpose, and the observer would be able to point along this plane to the objects elevated or depressed with regard to the horizon, as long as the visual ray is not intercepted by the table. Additions, easy to make, would render the observations more accurate. In short, any other means may be contrived in order to attain the same desirable purpose, which is, to increase as much as possible the field of the visual ray, in the vertical plane raised upon the ruler;

The numerical values of the angles and sides of the horizontal triangles described on a common plane-table, may always be easily determined by means of a protractor, a pair of compasses, and a scale ; but it has been attempted to obtain immediately these results, by improving the construction of the instrument ; Ozanam and others have proposed small tables, three sides of which serve as a protractor, the degrees being described on three rectangular chords, instead of a semi-circumference ; the fourth side, which forms the base, and the index, are divided into equal parts, and give the linear values ; *recipiangles* are also used for the same purpose, and these instruments have been indefinitely varied. The most simple of them have a dial placed in the common centre of the two rulers which compose them, and the index of this dial indicates the number of degrees passed over ; but the most ingenious carry at the end of one of their branches another dial so disposed, that, while the rulers move the space of one degree along the circumference which passes through their extremities, the index of this dial describes either a whole circle, or an arc of a circle, according to the ratio of the respective radii; in this manner, the minutes, or at least the fractions of a degree, are obtained; the index of a plane-table will serve as a recipiangle, by adding a similar branch to it.

Altitudes cannot be taken with a common plane-table and a common index; indeed, some composite plane-tables offer the means of supporting the index, the surface of the table being placed in a direction either parallel or inclined to the horizon, and even in a vertical plane; nay, the triangles observed in this plane may be described or estimated; but, in using these instruments, the position of the table must be changed for every altitude which we are to take; whereas, on the contrary, almost all angles can be observed, the table remaining horizontal, when the telescope, or such moveable index as was previously described, is properly elevated above the ruler; it is only requisite that a dial, or a graduated limb, should surround the ring inside of which the kind of trunnion, that is, the cylindrical piece of brass which supports the telescope or the moveable index, revolves on its axis; and that an index, or a vernier, fixed to this trunnion, should follow its motion. In order to obtain the linear values of the small similar triangles, and to avoid the necessity of having recourse to tables of tangents for the angles, the above-mentioned dial may be inscribed in a rectangle, the sides of which, being made equal to the diameter of the dial, and divided into nine-hundred or ninety equal parts, will represent all the tangents from 45° to 0°. These constructions may be indefinitely varied without any difficulty, and it is undoubtedly right to disregard them in general circumstances, as then nothing prevents us from employing the best calculated instrument for the operation which we are to perform; but I shall say it again, it is material, in reconnoitrings, that the same instrument may answer several purposes.

It has hitherto been supposed, that an officer was able to have a plane-table constructed at leisure; but circumstances may require that he should make one himself, with any kind of materials which he has at hand; in this case, he may form the table with any piece of board, and the stand with his cane, or three sticks; he may also make an index with a common ruler for drawing lines, a level with a plumb-line and an angular ruler, and a plumb-line with a musket ball and a piece of twine, or a slip of grass; two rulers, fastened together at one end, will supply him with a recipiangle, and if they are joined by means of a hinge made with any flexible substance, in such manner that, being laid over each other, and the hinge close to the edge of the table, one of these rulers can be raised while the other remains flat on the table, they will form an index, the field of which, in a vertical plane, is very extensive; this index may be graduated, and, in order to make it serve in taking vertical angles, it will be sufficient to place a support underneath the ruler which raises, and to apply a protractor, to one side of the other, in such a manner that its centre corresponds with the end of the hinge; this end being considered as the vertex of the observed vertical angle, the division on the protractor, through which the elevated ruler passes, will give, by approximation, the number of degrees it contains:* should no ruler be at hand, an index may be formed with needles, which will prove even more convenient than rulers in taking directions in a vertical plane; in fact, two needles will determine one direction, and a third needle will give the other; in short, we do with needles, on the table, all that may be done with staves on the ground. They may be used in all circumstances, and will afford both expedition and conveniency, if the table be made of soft wood, or its surface covered with pasteboard or cork.

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* This process is evidently founded upon the method of measuring an angle on paper, with a protractor.—*Translator.*

Fig. 55, 56, and 57, *pl.* 7, are intended to illustrate what has been said respecting the methods of increasing, on a plane-table, the field of the visual ray in a vertical plane.

Fig. 55 shows in what manner this result may be obtained by means of needles of unequal height; the rays projected in AC and BAM in the plan, may be raised to the positions A′C′ and B′M′ in the profile, which are determined by the heights of the needles, and the edges of the table.

Fig. 56 exhibits one of the several methods which may be used, in order to raise a vertical plane A′B′C, or A′B′C′, upon the index A′B′ represented by AB in the plan; by means of this plane, which admits of being graduated, we may satisfy ourselves with simply augmenting the field of the visual ray, or estimate the angle which it makes with the horizon, either by observing the point where this ray cuts the limb, or by using a moveable sight M, which may slide from B′ to C′; and also by means of an index A′M′ which turns round the point A′. It is supposed, in this figure, that the table of the instrument is circular.

Fig. 57 indicates one of the methods of raising the index, or the telescope C D above the ruler, the degrees being read on a dial P, and the tangents on the sides of a rectangle Q R S T; the ruler is supposed to be equal to the diagonal of the table, and the dotted lines in the profile show the limits of the vertical angles which may be taken with such an apparatus as is given in the figure; but these angles may be increased by raising the apparatus higher.

A small dial, similar to the axis upon which the index of a surveying compass revolves, may be adapted.

The plan in *fig.* 57 represents also two methods of dividing the sides of the table into degrees, the circumferences drawn for this purpose being described either from the centre of the table, or from the middle of one of its sides.

If a surveying compass be used, the magnetic needle (or rather the limb, when the needle is fixed in the direction north and south) describes the observed angle, and indicates its quantity; indeed the index moves freely in a vertical plane, but it does not show the number of degrees which it has passed over; however, if a limb, with its own index or a vernier, be adapted to the ring through which the index of the compass passes, this instrument may also serve in taking relative and absolute heights, after the box has been placed in a horizontal position by means of a small mason's level, or of a spirit level, either fastened to the box, or detached from it.

Should not a surveying compass be at hand, but only a simple compass, it will be easy to render this last fit for surveying, by tracing the degrees on the limb, or measuring them with a protractor; and by fixing to the box a ruler, or a stem, which may supply the place of an index. Indeed, it is a desirable thing that an officer should know how to make a compass himself, by means of any piece of iron he may find, and which has the property of a magnetic needle; and also, instrument in the vertical plane which passes through this line; no doubt, it is somewhat more difficult to erect a perpendicular when the sights are inclined; but this operation will be sufficiently accurate if a plumb-line be fixed to the centre of the instrument, which determines the point of meeting of the base and perpendicular.

A pocket-sextant will also be found a useful instrument in reconnoitring. In short, this operation requires the easiest and most convenient methods, in preference to those which are more elegant and precise, but have not the above qualifications.

It frequently happens that an officer has no plan to take, but only a height which commands a camp; or, perhaps, the breadth of a river, the declivities of the roads which an army is to follow, &c.

A *niveau à perpendicule** will give the declivities of a road, and may also serve in taking zenith distances.

The following method of measuring the elevation of an object, when its foot can be approached, is as simple as expeditious.

Suppose it were required to determine the height of the object B A, *fig.* 60; measure the length of its shadow B C, as also the shadow *b c* of a pole, a stick, or of any other object, the height *b a* of which is known; then make this proportion:

as *b c* : *b a* :: B C : B A

Should the height B A be given, and the distance B C be required, it may be found without any actual measurement, by substituting the following proportion for the former.

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* This is the instrument, resembling a Mason's level, the description of which has been given, and its use explained, in Article VII. pages 63 and following.—*Translator.*

as $b\,a : b\,c :: B\,A : B\,C$.

This method is evidently founded upon the property of similar triangles; from which it is known that the heights of the objects B A and *b a* are in proportion to each other as the lengths of their shadows.

In order to value the height of an object B A, *fig.* 61, place horizontally at C, upon the ground, a mirror or any other smooth surface, such as a vessel of water, &c. in such a manner, that you may view the image of the top of the object B A reflected from the mirror; then measure the distance E C at which you stand from it, as well as its distance C B from the bottom of the object; and, after ascertaining the height E D of your eye above the ground, make this proportion:

as $E\,C : E\,D :: C\,B : B\,A$;

or should the height B A be given, and the distance B C required,

as $E\,D : E\,C :: B\,A : B\,C$.

This method is derived from the principle of optics previously mentioned, that the angle of incidence A C B and the angle of reflection D C E, which are in the same plane, are equal to each other.

We shall observe that a vessel of water, or a piece of glass, the plane surfaces of which are exactly parallel, and which floats upon mercury contained in a box larger than the glass, should be employed, for this operation, in preference to common mirrors; as it frequently happens that the surfaces and frames of the latter are not accurately adjusted, wherefore the use of a level is requisite in order to place these mirrors horizontally.

The kind of mirror which the above-stated piece of glass forms, may also serve in verifying the others, and will suffice, in many cases, for determining the altitudes of the stars, which it reflects with accuracy.

Other applications of optics to Topography may be made.

Plane mirrors, for instance, will be found useful, in many circumstances, for reflecting a luminous point from one direction into another; and by means of convex and concave mirrors, objects, whose natural magnitude would not allow them to be properly observed, may be made to appear nearer and wider, or conversely to be concentrated.

These mirrors in reflecting telescopes, and the lenses in refracting ones or prospective glasses, afford the means of making new combinations, which increase their utility; a portable prospective glass is particularly necessary to an officer. He may adapt it to his instruments, or use it without them in observing distant objects, in order to extend his sight, diminish his fatigue, and avoid, in pressing instances, not only the errors which he might otherwise commit, but also such delays as might prove equally fatal.

It has been attempted to extend these properties, and to make prospective glasses serve in measuring immediately, by a simple glance of the eye, a height, the interval between two objects, and the front of a troop or of a work; in short, all the kinds of magnitude which it is the most important to ascertain in war.

Such is the object of micrometers.

The reader knows that the telescopes adapted to instruments have reticles at the focus, that is, cross wires which cut each other at right angles, and the intersection of which ought to be in the axis of the telescope, as otherwise the observation would not be made in the vertical plane which determines the number of degrees. An inclination of 45° is sometimes given to these wires, in order to prevent their covering the horizontal and vertical dimensions, but they are most frequently parallel or perpendicular to the horizon. Suppose that a moveable reticle follows in its motion either a horizontal or a vertical direction, the fixed reticles being in any of the three positions in which they may be placed; it is evident, in this case, that the deviation of the moveable and fixed wires will give the base of a horizontal or a vertical triangle, the vertex of which is at the centre of the object-glass; and also, that, if the fixed reticles be inclined 45°, the moveable reticle will form the hypothenuse of a small right-angled triangle which is the base of a pyramid having its vertex, likewise, at the centre of the object-glass; it is not less obvious that these triangles, or this pyramid which is formed upon the image, is similar to that which the respective dimensions of the observed object make with the centre of the object-glass; thus it will be sufficient, in order to determine the several dimensions of this object, to know its distance, which may be valued from one of those dimensions being known. For example, if we are acquainted with the mean height of a foot or a horse-soldier, or with the space which a battalion or a troop usually occupies, we shall be able to determine its distance from us with as much precision as war requires.

This supposes that we know every thing in the image; in fact, its distance from the object-glass is known, and the place of the focus may be easily found. We may measure the deviation of the reticles by means of divisions or of a net-work traced upon a plane glass, which, according to circumstances, may be polished, unpolished, or coloured; we may also value this deviation, as astronomers do with *Auzout's* micrometer, by counting on a limb the number of turns of the screw which occasions the motion of the moveable reticles. When we are obliged to use any micrometer which we have at hand, one or two observations, upon objects of known magnitude and positions, will give the ratio of the turns of the screw to the deviation of the reticles; but should we order an instrument to be purposely made, it is proper and easy to determine this ratio before the instrument is constructed, in such a manner that it may serve in forming simple and commodious tables.

The mechanism by which the wires are moved is simple, and does not differ from that which is almost always used in order to procure that gentle and insensible motion which optical instruments require; it only consists of a screw, a few springs, and of one or two wheels which communicate the motion of the reticles to the hand that indicates the turns of the screw.

This mechanism, however, notwithstanding its simplicity, can scarcely be adapted to prospective glasses intended for reconnoitring, as it would render them still too complicated, but it may be used to advantage for delicate astronomical operations.

Various methods of supplying the place of fixed and moveable reticles in these glasses have been contrived; some substitute for them a plane-glass, upon which degrees or aliquot parts of the distance from the focus to the centre of the object-glass are traced: these divisions are frequently drawn on the horizontal diameter, and sometimes also upon the vertical diameter; finally, a net-work only may be used, and the magnitude of the objects determined by the number of squares which their image covers; such is the micrometer of Brander, an optician of Augsbourg,* and such is, likewise, or nearly so, that of Mr. Schamhorst, a Hanoverian officer; this last was used in the present war, with some modifications adapted to it by *Souhait*, a chief of battalion in the corps of engineers.

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* As a description of Brander's micrometic prospective-glass may be acceptable to some readers, we shall give it in this note.

This instrument consists of a small tube C D E F, *fig*. 62, containing two convex lenses C D and E F, the focal distances *i b* and *n b* of which are equal, and so disposed as to correspond with the middle of the distance between the lenses; in this point, or common focus, a micrometer G H is placed, and very delicately traced on a plane-glass, upon which the object-glass E F transmits the image of a distant object A B; this image appears likewise at the focus of the eye-glass C D, wherefore it ought to be distinctly seen when the eye of the observer corresponds with the other focus in *m*, for since the rays *a l* and *b k* are parallel, and *a b* is equal to *k l*, it follows that we have the angle $k\,m\,l = b\,i\,a = A\,i\,B$; thus the object must appear exactly of the same dimensions as if it were observed by the naked eye.

The micrometer G H is a glass of which the two opposite surfaces are plane; two parallel lines are traced on one of them with a diamond, and divided into intervals which are exactly equal each to $\frac{1}{40}$th of an inch; they ought to be very delicately expressed, and this is the most difficult part of the instrument to execute. Should the distance from the focus to the object-glass be made one inch, one interval of $\frac{1}{40}$ in. will be the chord of 1° 26′; $\frac{2}{40}$ in. will give the chord of 2° 52′, and $\frac{3}{40}$ in. that of 4° 18′, &c. But, should this distance be 2 inches, one interval of $\frac{1}{40}$ in. would, in this case, be only the chord of 43′, and if the same distance were three inches, the arc corresponding to $\frac{1}{40}$ in. would not exceed 28¾′, &c. the reason is that in this instance, the angles and their chords preserve the same ratio, so long as the former are very small; wherefore, the visual angle at which the object appears to the eye may be instantly observed and indicated, let the distance be what it will.

It is to be observed, however, that this kind of rectilineal graphometer ought not to be continued further than 4 or 5 degrees on each side of the diameter, as a greater distance would occasion errors in

The divisions are traced upon the glass with the point of a diamond, or else with fluoric acid; and for the metal wires that were sometimes used, silk-worm or spider's web is now substituted, and fixed on the glass

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the measure of the angles, on account of the distortion of the parts towards the edge, and particularly if the focus of the lenses were small; wherefore it is preferable to trace the scale according to the following table, by carrying the chords for each half degree on each side of the diameter, and assuming the distance from the focus as the radius; in this manner, the measurement may be extended to angles of 18 and even 20 deg. This is the table:

Angles.		*chords in* 1000.0		*Angles.*		*chords in* 1000.0	
deg.	*min.*	*parts of the radius.*		*deg.*	*min.*	*parts of the radius.*	
0.	30.	8.	7.	5.	30.	95.	3.
1.	0.	17.	4.	6.	0.	103.	9.
1.	30.	26.	1.	6.	30.	112.	5.
2.	0.	34.	8.	7.	0.	120.	9.
2.	30.	43.	5.	7.	30.	129.	4.
3.	0.	52.	2.	8.	0.	137.	8.
3.	30.	60.	9.	8.	30.	146.	2.
4.	0.	69.	5.	9.	0.	154.	5.
4.	30.	78.	1.	9.	30.	162.	7.
5.	0.	86.	7.	10.	0.	170.	9.

The apparent magnitude of the objects may, therefore, be easily estimated and compared by this means, since the image, which shows itself in the micrometer, indicates its comparative magnitude by the number of intervals that it fills; thus we may conclude that the magnitude of an object, the image of which occupies two intervals, is double that of another object which only occupies one, both objects being seen from the same place. Likewise, if we successively observe an object from two different points, and find that its image occupies twice as many intervals in the second observation as it did in the first, it is certain that its distance from us, at the time of that observation, is only half of what it was when the first was made; we may determine, in the same manner, either the height or the breadth of objects, when we know their distance; and reciprocally, this distance may be estimated from the height or the breadth of the objects being known; in the first case we have, with an imperceptible quantity of gum or of varnish. Our opticians make these divisions much finer than is required even for the most difficult operations relative to reconnoitrings.

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as the distance from the focus to the object-glass is to the length or height of the image in the micrometer, so is the known distance of the object to its height or breadth.

Fig. 65, as $ae : fg :: ad : bc$.

and in the second case

as $fg : ae :: bc : ad$.

Brander constructs two different kinds of tubes; those A, *fig.* 63, are vertical, and the images of the objects are conveyed within them by means of the mirror C, which the screw *d* serves to incline according to the positions of the objects; the other kind of tubes, *fig.* 64, are the same as the former, except, however, that they are horizontal, and may be directed straight to the object, which appears to the eye in *a* by means of an inclined mirror; in both tubes, the cylinder D or *b* may be lengthened or shortened so as to suit the sight of the observer. Plane-mirrors are adapted to these tubes, not only for giving the objects the erect instead of the inverted position, but also in order to distinguish by the eye, with greater facility, the number of intervals or chords which each object occupies on the micrometer, as with other glasses the motion of the hand which holds the instrument would render this observation difficult.

The other component parts of Brander's micrometic prospective glass, which the plate represents, are a small shade O, containing a black-coloured glass which is used and placed before the eye-glass D, *fig.* 63, when luminous bodies are to be observed.

A cover P, which is pierced with a small orifice, in order to be posited before the object-glass in observing luminous bodies.

The micrometer Q; the distance from the focus to the object-glass, which serves in regulating the divisions of the micrometer, should be marked on this tube.

The net-work R, traced on a plane-glass, and each side of which measures 2 degrees; this net-work may serve for taking plans, by being substituted for the micrometer.

S is an unpolished plane-glass, which, if it be also substituted for the micrometer, will give a *camera oscura* for observing luminous bodies.

Translator.

In case of necessity, astronomy might supply us with other instruments useful in war; Bouguer's heliometer, for instance, may be rendered portable. The construction of this instrument is very simple, and the use of it presents no difficulty; a telescope, with a single eye-glass, carries two object-glasses, or two half object-glasses, which are moveable, and give a double image of the observed terrestrial object or heavenly body; of the sun, for instance; if the object-glasses, or one of them be moved until the images touch each other, the interval between the centres of these glasses will give the diameter of the sun, as measured by the inclination of the two rays which separate them. The dimensions of the objects which may appear at once at the focus of a telescope, or the intervals betwixt them, might be measured in the same manner. Finally, nothing would be more easy than to combine the idea of a double object-glass with that of a micrometer, and to apply the result of this combination to estimating the distances of objects comprised in a more extensive field of view, or the intervals between them, taking two directions at once, and, in short, to procuring a substitute for reflecting instruments; at least, within certain limits.

We should, therefore, continue Rochon's ingenious experiments on acromatic prisms, as well as on prisms, or object-glasses, formed of substances which give a double refraction; and on the means of applying this property, the deviation of the images, and the distance between the two foci, to the measurement of the angles which any objects make with each other, and even of the angle formed by two objects, one of which is very near us, and the other very distant.

Perhaps means will also be found for determining distances from the quantity which the tube that carries the eye-glass is drawn out. Several officers and opticians have already applied this idea to common prospective-glasses, and attempted to estimate the distance of two objects placed either very near to or very far from the eye, from the necessity of increasing or diminishing the distance between the eye-glass and the object-glass; a kind of approximate scale of distances being traced upon the tube of the instrument.*

The resources which optics afford, and the multiplicity of instruments which we may combine in various ways for the purpose of rendering their use applicable to necessities of all kinds, are undoubtedly affected with a great number of errors resulting from the difficulty of working the glasses accurately, and, as is the case with lenses, from the figure we are obliged to give them; the smallness of the field, in common prospective glasses, limits the extent of the visual ray, and diminishes the clearness of the observed objects, while a large field affords the contrary properties, but bends the

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* This process requires that during the motion of the object-glass the instant at which the image is the most distinct should be seized, and it can only serve when the distances of the objects from the eye are sufficiently great to require the eye-glass to be drawn out an observable quantity; the approximation will never be rigorous, and this means would not deserve to be noticed were it not for the means which every officer possesses of determining for himself the divisions of his own prospective-glass from a series of experiments, and of marking them for a time, with the point of a needle, upon the tube which carries the eye-glass, until habit and successive corrections have rendered his scale somewhat more accurate; when he may have them, at last, permanently traced upon this tube.

Many ingenious contrivances, for analogous purposes, are given by Dr. Brewster in his Treatise on philosophical instruments.

Translator.

Therefore, the odometer alone is of very limited utility; it completes, so to speak, the number of expeditious instruments, when its use is combined with that of the compass and the barometer.

The barometer is the only instrument with which altitudes may be taken with sufficient expedition, and in sufficient numbers, to allow the respective elevations of places to be indicated on a map; an important improvement, which is unattainable by the other instruments generally employed; besides, its use affords a means of taking from the summit of a mountain, the map of all the accessible points of its counterforts, or of the plain, which may be discovered, and where barometrical observations have been made. The barometrical observation at the summit of the mountain, ultimately gives the absolute and relative heights of all the points that are seen, these being compared with each other, and with the principal summit. These heights are so many vertical bases or known sides in the triangles which the different points form with the central station and the plumb-line; wherefore it is only further requisite, that the necessary angles for determining the pyramid, or the trigonometrical prism, should be taken from this station with a repeating circle, or any other instrument.*

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* Suppose that the differences of level A A′ A M, of the three points A, B, C, *fig.* 66, are known.

If in addition to these differences, we take from the points A, B, C, the angles which the visual rays make with the plumb-line, we may easily determine the vertical triangles A A′ B, A C M, and B C C′.

The three sides A′ C′, B C′, A′ B, of the horizontal triangle being thus known, its angles may be calculated without any difficulty, or obtained by construction. (See, for the calculation, the last formulæ in the note*, page 57.)

Two material imperfections limit the use of the barometer in taking altitudes.

First, the little sensibility of this instrument allows it to be applied to the above purpose only when the differences of level are rather great; this defect arises from the density of mercury. Thermometers may be rendered sensible, at the will of the observer, by varying the liquids intercepted in the tubes; but even supposing that we might succeed in finding or in composing for the barometer a liquid less dense than mercury, although sufficiently fixed not to be converted into vapour in a vacuum, yet there would remain a condition to be ful-

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By this method, the survey of a country of which the level was taken, only requires, that the angles of inclination, or the inclination of the lines which connect the stations, should be measured.

But if the station C cannot be seen from a station B, or should we wish to refer the measures of all the angles to a single station A, we must also observe the angles which, like B A C, are comprised between the lines directed from the point A to such other stations as B and C. On the other hand, we may dispense with taking the angles of inclination like B C C′, and determine them without repairing to the lower points, such as C.

Supposing a single station A, the sides A B and A′ B, C M and C A, of the vertical triangles A B A′ and A C M, are to be calculated as above; these triangles will give A B and A C, and the angle B A C being determined by observation, B C will be obtained.

Having B C, and C C′ being also known in the vertical triangle C B C′, the third side B C′, which is common to this triangle and the horizontal triangle B A′ C′, is to be determined; this last may then be easily constructed, since A′ B and A′ C′ are already known.

Lastly, B C and C C′ may serve for calculating the angle of inclination B C C′, if required.

This last method affords the means of surveying mountains, by levelling with the barometer and making a single trigonometrical station at one point of the summit whence all the objects of which the level was taken can be seen.

filled, which is the portableness of this new instrument; inclined tubes have been proposed, where the mercury follows the diagonals of rectangles having their base so much longer as the tube is more inclined, and their heights indicated by the variations of the mercury in the vertical tube, but this construction renders the instrument inconvenient, and, what is worse, much less certain, as the friction of the mercury against the interior surface of the tube ought to be taken into the account.

The delicacy of the mechanism by means of which the motion of the mercury is communicated to a hand, or to a vernier, which moves upon a dial plate, makes it liable to be deranged, while its weight and friction still diminish the sensibility of the instrument; however, the best barometers are made according to this method, and they ought to be preferred to any other, unless no inconveniences are found, in practice, in applying the ingenious scheme which *Conté* proposed to use for taking heights, barometers with tubes inclined but cut, and to measure their altitudes by the quantity of mercury which overflows.

The second source of the errors which may be committed in using the barometer, is our uncertainty respecting the causes of the variations of the mercury, and the nature of the corrections which the observations require; we ought to recur to the works of the most distinguished geometers and meteorologists for an illustration of the calculations, hypothesis, and observations upon which their formulæ are founded; time may remove our doubts and enable us to know the respective influences which the temperature, the winds, the vapours, the gasses, and other fluids mixed with the air, exercise upon the oscillations of mercury; and also, in what manner these influences, which, taken separately, are insufficient for explaining the problem, act all together, and give rise to a multiplicity of partial and sometimes simultaneous modifications in the atmosphere;* in short, it belongs to learned bodies, encouraged by governments, to form a plan of observations and experiments relative to this phenomenon; to render the instruments and methods uniform; to entrust the work to distinguished observers, and to give them the necessary assistance in a series of operations which will require courses, a choice of instruments, and perhaps the use of machines, such as the areostatic machines.

It follows from what has been said respecting the barometer, that the instruments particularly adapted to geodesic operations are as yet preferable to it for taking the exact altitude of heights; and even that levels, which are constructed and used with care, have some advantage over it for this purpose; indeed, the precision which the barometer gives is sufficient in a reconnoitring when the differences of level are rather great; but, should they be small, levels ought to be employed in preference, if these differences are to be accurately determined and we have time to value them so.

Levels have been indefinitely varied, and one of the simplest is the water level;† by using them successively at the requisite stations, we obtain the heights of the summits of all the angles which a series of triangles, or the lines drawn in any map, form on the ground.

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* Since the publication of this Essay, Biot has investigated the influences of these causes, and solved the problem in a manner that leaves but little to be desired. He has also computed tables for facilitating the calculations, which render them extremely simple and easy. His investigations and tables will be found in the first volume of this work.

The works of Saussure, Deluc, and the more recent Memoirs of Kirwan, Dalton, Leslie, and Ramond, a member of the French Institute, may also be consulted.—*Translator.*

† See the description and use of this level in page 59, Vol. II. *Translator.*

When the levelling to be carried on embraces a great extent of ground, the curvature of the earth must be considered; and should the stations be very distant from one another, the errors of refraction, which increase as the distances, and vary according to the state of the atmosphere, ought to be taken into the account. Tables, which it may be useful to perfect, in order to use them in rigorous operations, offer every requisite means of correction applicable to reconnoitrings, when these last require some levellings which time allows to be performed.*

We have taken a view, in the two preceeding articles, of the principal instruments that may be used in reconnoitring. The modifications they require, and the rough constructions which may supply their place, or extend their use, and afford immediate resources in unforeseen circumstances, have also been considered.

But even the most fertile mind in expedients cannot alone suggest means for all circumstances, and the resources which we may derive from our imagination do not supply the place of positive knowledge, since, on the contrary, this knowledge ought to direct our combinations and contrivances. Therefore an officer should not neglect to acquire it, and rely solely upon his own experience: the information which he must have may be easily obtained, and will double his means; and if he also possess the spirit of his profession, the ground, and the circumstances in which he may be placed, will teach him the rest. Let him attend in his studies to both theory and practice; for, if much art and intelligence be requisite in using the most delicate instruments and process, coarser instruments and methods require a more experienced observer: similar, in this respect, to an able workman, who alone can make a skilful use of an imperfect tool.*

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* Tables of this description will be found in the works of several authors.

What has been said in the note*, page 144, of this volume, respecting the Barometrical Levelling, is also applicable to the other methods of performing this observation.

In general, there is scarcely any means which may not be applicable, in one circumstance or the other, to a branch of service in which nothing is precisely determined, but every result an approximation; and where an order which is given admits of no answer, but requires acting, without the want of the usual instruments being any excuse. In short, no contrivances should be despised, as even the smallest assistance may facilitate the business. Imagination creates means, while erudition reminds an officer of all the resources which time and previous operations have suggested: his intelligence enables him to select such of them as are the most suitable for his purposes, and the practice he has acquired teaches him the best method of applying them.

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* A notice in which all the instruments known would be compared, and a historical account given of the gradual improvements relative to them, would facilitate their use, and guard the observer against the errors of their previous application. It would particularly serve in perfecting those instruments by each other, as the means of transferring from one to another, the ingenious dispositions which some of them exhibit, would thus become more conspicuous; besides, a notice of this kind would leave in the mind of an officer the remembrance of a number of different combinations, by means of which he might contrive instruments adapted to reconnoitrings, and have them executed in haste.

This article is intended to convey such notice, but the limits of this Essay did not allow the subject to be treated of at full length.

thods just explained, or by any other, and plant a staff D, in the direction C A, at any proper distance from C; place also a staff E, in the direction C B, but at such point that C E is to C D as C B to C A; then measure D E, and make this proportion,

as C D or C E : D E : : C A or C B : A B.

The ratio of C E to C D may evidently be determined without any difficulty, since C D may be made of any length, and C A and C B were measured.

Altitudes may be measured by means equally easy.

First, should it be required to measure the height of the object C A, *fig.* 71, the foot of which is accessible.

Two poles ed, fg, of unequal lengths, being set up parallel to the object, in such a manner that the visual ray d A, directed to the top A, grazes the tops d and f of the poles, measure the distances eg and eC; then make this proportion,

$$\text{as } dh = eg : hf :: dK = eC : KA.$$

K A being thus determined, it only remains to add C K to it, which is equal to the length ed of the shorter pole.

The same operation may be done with one pole, as follows, see *fig.* 72, in which B A represents the required height.

After the observer has fixed a pole D C upright in the ground, by trials, so that, having laid himself on his back, with his feet against the bottom of that pole, he may see the top of it, and the top A of the object B A in the same right line F A, the distance F D, from the eye of the observer to the foot D of the pole, will evidently be in proportion to the length D C of this last, as the whole distance F B is to the height of the object B A, which will consequently be obtained by making this proportion,

as F D : DC : : F B : B A.

Secondly, should any obstacle prevent the observer from approaching the foot of the vertical axis that passes through the summit of the object the height of which is required, the inaccessible distance may, first, be determined by one of the methods just explained, and the remainder of the operation be made according to the two last problems.

Or else, suppose the height of the inaccessible object B C to be required, *fig.* 73.

A pole I K being set up at any point I of the ground, another pole M N, longer than the preceeding, is also to be fixed, in such a manner, that the tops K and N of these poles are in the same right line K C as the top C of the object; this done, the observer is to place himself behind the pole M N, and to direct a visual ray N A along the tops of the poles, in order to determine the point A where the line N K or C K produced meets the ground; next, another point M′ being taken in the prolongation of the line A I M, and the triangle A′ M′ N′ determined by the same method as the triangle A M N, the distances A M, A A′, and A′ M′ should be measured. Now, it is to be observed, that, should the triangle A′ M′ N′ be applied to the triangle A M N, as shewn by the triangle A N D, this last will be similar to the larger triangle A C A′; therefore,

$$\text{as } AM : AB :: MN : BC.$$

and

$$\text{as } AN : AC :: AM : AB :: AD : AA'.$$

Hence, because of the common ratio A M : A B, we have

$$\text{as } AD : AA' :: MN : BC.$$

or,

$$\text{as } d : D :: h : H = \frac{Dh}{d}$$

In this formula, *d* and D are the difference of the bases of the smaller and larger triangles, the respective heights of which are expressed by *h* and H.

It is evident that the process represented by *fig*. 73 is also applicable, as well as the formula $H = \frac{D\,h}{d}$ to the case of the Jacob's staff, the *niveau à perpendicule*, &c. and other instruments being used.

More rough means may give the heights and distances when it is only wished to estimate them with little precision.

For instance, instead of poles, in the preceding examples, a graduated staff may be substituted, which is held in the hand; the hand of the observer being at the height of his eye, he examines at what point the visual ray which grazes the summit of the object, cuts the divisions of the staff; rulers, forming a right-angled triangle, which we apply to the eye, offer another method of approximation; a thousand different ones may be contrived, all of which consist in forming small triangles similar to those which the eye makes, at one or various stations, with several objects, or with one object and the horizon. The remainder of the operation is reduced to the measuring of a base which determines, or serves in determining, one side of a larger triangle, and easy analogies give afterwards the required dimensions.

Another method, which differs from the preceding, but may be applied with as much facility, is that ingenious artifice, by means of which peasants take the distances of inaccessible objects: they place the end of the corner of their hat, their eye, and the object, in the same right line, then turn upon one of their heels,* without altering the vertical position of their body, and observe an accessible object which is situated, like the former, in the direction of the eye and the corner of the hat; they measure its distance from the point of observation, and conclude that it is equal to that of the inaccessible object.—Instinct and experience have taught them, that, by using this process, they transfer a line, which cannot be passed over, to an accessible ground, and that the length of this line will not change, provided the positions of the hat and the eye remain the same with regard to each other and to the ground. In fact, it may be easily seen that, in this operation, the eye, the feet of the observer, and the corner of his hat, determine the generating triangle of a cone, having its vertex at the eye, and the base of which remains the same if the other two sides do not vary during the rotary motion of the observer.

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* The error which undoubtedly affects this approximate measurement will be smaller, if the observer can perceive an accessible object by simply moving his head round, instead of turning upon one of his heels.—*Translator*.

Fig. 74 shews the generation of the cone formed by the visual ray A C′ which the observer directs, by turning upon himself as round an axis A B, from the inaccessible point C to the point C′ which can be approached. It is evident that the distance B C′ is equal to B C, as they both are radii of the circular base of the cone; wherefore B C will be obtained by measuring B C′.

This method, as well as those which are founded upon a position of the arm, or a motion of the body, in any direction, are generally affected with errors of a certain magnitude; but these errors may be diminished by supporting those parts of the body which ought not to move; for instance, instead of using the corner of a hat as a point of direction, in the operation just explained, we may prefer a cane supported against the knee, or any other means of the same description. In short, whether these processes or instruments are used, previous experiments, repeated observations, and a great practice, will allow the operations to be performed with such expedition and precision as appear scarcely possible at first sight.

In the same manner, we may also measure all distances by pacing, without any great error; this expeditious means is most frequently sufficient, and nearly the only one which may be used in the field. In a word, an officer's own person, as well as his assistants and horse, are, if I am allowed to employ this expression, the first instruments which he should study and regulate.

The natural step of a horse which was properly broken will also serve an officer in taking distances with as much expedition as circumstances may require; and particularly if he be master of the horse. The head of this animal gives the first point of a direction which is to be determined, and its height and other dimensions may afford the means of estimating the breadth of a road, a bridge, a defile, as well as the depth of a ford, a shoal, and of wet and marshy places.

It is especially requisite that an officer should be acquainted with his own dimensions; indeed, the names of measures in use among all nations, such as, pace, foot, &c. sufficiently indicate that measures were originally taken from the dimensions of the human body. Therefore, an officer ought to know the proportion that the natural measures he may employ bear to those which were agreed upon, and are used, either in his own country, or in those where war may be carried on; his stature, the height of his eyes above the ground where he stands, and particularly the space which he passes over in a second at a slow step, quick step, and pressed time, are quantities which he must ascertain from a series of experiments, as they will supply him with useful data.

No general results can be pointed out respecting experiments of this kind, as each horse and each observer require particular trials; an officer should make his horses go, at all kinds of steps, and for a given time, over a space which he may afterwards actually measure with precision; or else, over a space which is known, but an account being taken, by means of a good and well-regulated watch, of the time the horses were in going over this space; the officer himself should do the same. Let him repeat those experiments on different kinds of ground, and estimate on roads, the declivities of which he knows or can measure, the influence which these declivities have upon the pace of his horse, or upon his own; in this manner he will accustom himself to value the steepness and length of a declivity from the length of time employed in ascending or descending it. It is important, likewise, that he should consider every circumstance relating to these experiments, such as the fatigue of his horse, or his own, and repeat his trials at different times. Lastly, it is proper that he should reduce his observations into tables, and comprehend in these tables, in their respective classes, not only the mean which the same series of experiments has given, but also the extreme terms; for, it is a negligence but too common, respecting sciences founded upon observation, to consider the means only, and not to pay sufficient attention to the extremes, which alone can explain extraordinary cases, or serve in resolving them.

It is easy to perceive what advantageous use an officer may make, in pressing circumstances, of his guides, the men who form his escort, and particularly of his permanent assistants, in order to take a direction in haste, and approximate measures. His previous labour ought not to discourage him, as he will be indemnified for it when he is actually practising; the habit of measuring distances rapidly, allows a great extent of ground to be described, in war, within a short time; it quickens the work, and multiply the results: but it particularly forms the *coup d'œil,* and is therefore the best preparatory qualification for surveying by the eye alone.

ARTICLE IX.

On Surveying by the eye alone.

The last kind of reconnoitrings remains to be considered; in which, instruments cannot be used, nor the distances measured even by the pace of man or horse; to this kind belong the observations made for the purpose of reconnoitring, in a short time, a country where an officer is compelled to proceed with the same expedition in his operation as if he only was a traveller; such are the circumstances in which it is required to take in great haste the environs, the site, and, if possible, the general configuration of a fortress, the investiture of which is to take place without the garrison suspecting it: the position occupied by the enemy, before we attack him; his movements, marches, the line of his outposts and quarters: the banks of a river, or of a stream, where he has thrown up *têtes de pont*: the defiles of marshes and mountains, which he is watching, and proposes to defend: in short, the aforesaid kind of reconnoitrings comprehends the observing of all the particulars that, in maps, are relative to the representation of the ground, and in the field, to the movements and operations of every description.

First, let us examine what means of assistance may be found, as well as the signs, or the indices and analogies which may serve as guides in completing outlines, determining distances and other principal dimensions of the ground, and afford a base for the representation of this last.

The outlines, printed maps, and other materials of every description, with which an officer may be supplied, will be found particularly useful in this circumstance.

Material advantages would be derived for this branch of service from the execution of the excellent idea which *L'Espinasse* has suggested, of having slightly engraved beforehand, according to the scale adopted for maps relative to reconnoitrings, the outlines of the places, roads, and courses of water of all the countries where war may be carried on; these outlines being taken from accurate maps either drawn by hand or printed.*

But, however useful all these means of assistance may be, they will prove insufficient, and we shall now investigate the manner in which the most treacherous of our senses may supply them.

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* This excellent scheme might be executed as follows, and the application of it extended.

Government might collect, in a series of copper-plates, all the triangles or points previously determined by means of Geodesic operations, or astronomical observations. In proportion as an error might be discovered, it should be rectified, and the results of all new operations be added to those of the preceding ones. In this manner, correct outlines should be permanently at hand, and by working off gradually as many copies of them as circumstances might require, and distributing them to the engineers or other officers engaged in surveys, they would serve them as guides and points of departure in their operations.

It would be further requisite, with regard to reconnoitrings, to add to these outlines in another collection of copper-plates, and according to a convenient scale, all the topographical details the accuracy of which may be relied upon to a certain degree, and to correct and augment them as new reconnoitrings will afford the means of doing so.

We do not see objects as they actually are, and besides the errors arising from this circumstance, our eye, which judges with accuracy of colours only, and cannot estimate extent without the assistance of another sense, ceases to perceive, beyond a certain distance, a clear and distinct image of extent, and even of colours. Bodies are then obliterated, their colours appear confused and faded, and the luminous rays which they convey to the eye are rarified and dispersed in a progression which follows the squares of the distances.

Even the idea of extension is formed in our mind only from the succession of bodies which we consider, as we know time from the succession of our ideas; hence it follows that we cannot estimate distances with certainty, but by means of the interposed objects, and that we augment or diminish them in our imagination, according to the number and position of these objects, and to the space which they occupy.

Other errors arise from the little habit we have to consider things in the point of view in which they offer themselves; accustomed as we are to see from a small distance all the objects that environ us, and to observe constantly round us triangles, the sides and angles of which have only differences, with regard to each other, which our mind easily estimates with accuracy, we give ourselves up to all kinds of illusions, when the objects are strange to us or ill defined by our judgement, and also when they form with our eye triangles of which the sides and angles are very unequal.

Thus we exaggerate, in all ways, objects that are very near us, but which a fog or obscurity makes us believe to be further distant; in this manner, likewise, our eye confounds and reduces to nothing the dimensions of very remote parts of the country which it perceives, creates giants, forms phantoms, and dissipates them. Through similar illusions, too, mountains appear nearer to us than they actually are, upright towers seem to be inclined, and crooked roads to be straight: in fine, we mistake the face of a distant pyramid, which rises above the verdure of a forest, for a road passing across it.

The most common illusions only have been pointed out, and others present phenomena which are still more remarkable, and capable of startling and deceiving us; such as the appearances arising from atmospherical refraction. Mirage seemingly rises towns and villages above ground, and makes them appear as if they were encompassed by a vast sea; if at night, in clear weather, we descend a mountain, or follow the edge of a valley, the low grounds on both sides of the road, as well as the valley, have the appearance of lakes or of an indefinite deep sea; the summits of steeples, and the tops of trees, scarcely dispel this illusion, although they inform us that the pretended waters, which we believe we see, are only a thick and white fog forming a separation with the pure and serene air in which we are placed.

However, reconnoitrings may be made during the night. Twilight is the most favourable moment for observations made in presence of the enemy; but, even by day-time, the obliteration of contours, the gradual weakening of tints, the effect of light and shade, and particularly the novelty of the objects which we are observing, will deceive our eyes. In what manner, then, shall we be able to guard ourselves against such deception, and avoid the consequences of it? The answer is, by habit.

It is from habit that even a child acquires the idea of extension and measures: we owe to the same cause that facility which we possess of estimating the most common dimensions, as they are those which we the most frequently have before our eyes; and it is for want of habit in observing distances, or any other kind of magnitude, which we seldom have the opportunity of examining, that we find it so difficult to determine them. Therefore, an officer should accustom himself to Geodesic operations and measurements of every description, and particularly to those which, as the surveys performed with the compass and by pacing, are carried on rapidly; as his sight, which the practice of these operations incessantly rectifies, will acquire precision by degrees.

The habit of surveying, but particularly the formation of triangles, still teaches us how to refer all forms of the ground to other forms which are more simple and more easily defined. This ingenious art, which painters themselves sometimes employ, consists in inscribing mentally regular figures in all compound ones; the connection of the principal figures forms imaginary outlines which guide us in our observations.

Another advantage which an officer derives from being accustomed to Geodesic operations is that of choosing proper stations, and of considering objects in such points of view as are the most favorable for obtaining a knowledge of them: he also acquires information by their means, respecting the method of producing lines of direction on the ground; and these lines, being skilfully produced, give new intersections, and allow the ratios of the lengths and inclinations of the various lines to be estimated at sight.

It is not to be expected, however, that the habit of measuring will alone be sufficient to prevent mistakes in this estimation; but the principles of optics afford us the means of detecting and rectifying our errors, by pointing out their sources.

We learn from lineal perspective the method of transforming geometrical magnitudes into apparent ones; and this science may also teach us how to deduce the former from the latter. The same object gradually appears smaller as it becomes more distant; the optic angle, that is, the angle formed at the eye by the luminous rays from the extremities of the object, diminishes as the distance from this last to the eye increases; wherefore an observer may conclude the distances of known objects from the opening of the optic angle. According to the same law, parallel lines seem to be converging, prisms appear like pyramids, cylinders like cones, and spheres as ovals. In short, this law uniformly alters every kind of magnitude; but these alterations are only perceptible when the objects are placed at a certain distance, and our judgement will rapidly dissipate the illusion, after daily practice has rendered it more quick and more certain. The knowledge we possess of the causes and effects of this illusion will enable us to determine the true forms of the most remote objects, and thus remove all impediments, arising from distance, to the accuracy of our observations.

The position of objects cannot be estimated from lineal perspective alone, as, amongst many other errors, all kinds of magnitude observed under the same optic angle would appear equal, and convergent lines could not be distinguished from others which are parallel, should not aërial perspective acquaint us with the method of discerning, by means of the shadows, the enlightened parts, and the differences in the brightness of the tints and colours, the unequal magnitude of objects seen under the same angle, as well as the different situations of other objects which have similar optic dimensions. Lineal perspective allows only lines to be seen, and angles to be estimated, while aërial perspective gives bodies to the objects: the natural philosopher learns from it in what manner all kinds of illusions and effects of optics may be produced by weakening the light, the tints, and the colours. It also constitutes the only means which draftmen and painters have of making objects appear distant, and placing them in any plane they choose. This multiplicity of ingenious processes is founded upon the weakness and imperfection of our sight, which affect the appearance of the objects that we are considering; wherefore the alterations thus produced in this respect may also serve in estimating distances. If an officer is not sufficiently acquainted with the rules observed in drawing and painting, and with the method of applying them properly, he ought to make up this deficiency by habit, and compose for himself, as painters do, a scale of the different tints and colours: he should also, similarly to them, accustom himself to divide a space into several imaginary planes connected together, and refer all the objects to the planes which are respectively the nearest, so as to distinguish, and thus determine, a succession of sensible terms in this infinitesimal series of the diminution of light. In fine, he should particularly learn to distinguish the natural effects of light from those which occasional causes may produce, as well as the influence that shadows, and all kinds of reflexes, thrown by some objects upon others, may have on the enlightened parts of the latter.

The errors to which our eyes are subject vary with the places, the seasons, and the hours of the day; therefore, an officer should observe similar objects in different places, and at different seasons and hours: he should examine them alternately in flat and hilly countries, and endeavour to obtain true results, notwithstanding the singular mistakes which are to be apprehended, for want of interposed objects, in open plains, chains of mountains, and upon lakes and seas: he ought to consider attentively, likewise, in what manner stronger refractions obliterate the features of objects, and apparently magnify their dimensions, during rain, mist, and fog; and how the extreme whiteness of snow, on the contrary, by its contrast with all other colours, renders more perceptible the tints of the objects it does not cover, and diminishes seemingly the dimensions of these last, which it enlightens and makes appear nearer. Other observations will enable him to perceive the modifications in optical phenomena, arising from the different brightness of the celestial bodies, of the sun and moon, in the zenith, at the horizon, near the time of their rising and of their setting; also the various effects produced by accidental lights, such as the aurora borealis, and any other light; as well as the changes which these lights occasion in the colour of the clouds, and the azure of the atmospheric vault; lastly, he will see in what manner these changes in their turn affect bodies and our organs, alter the forms of objects, transform one colour into another, and create illusions indefinitely varied.

Natural philosophy, and occasionally Geometry, may also guide an officer in his practical studies, as these interesting branches of science will first disclose to him the facts, illusions, and phenomena previously remarked.—But, similar in this respect to a painter, nothing will be equivalent to observation and practice, which sometimes even supply the place of scientific knowledge.*

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* The two following simultaneous effects of perspective require particular consideration, and can be observed and verified at every instant.

In this manner, the inhabitant of mountains discerns their actual forms in their appearances, concludes their distances from their tints, and distinguishes those parts of the chain to which the different summits belong, by

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1. The dimensions of objects decrease as their distances from the eye of the observer augment.

2. The intensity of light diminishes in the ratio of the square of the distance from the observed object to the eye of the observer.

Demonstrations.—1. The eye of the observer being placed in a point O, *fig.* 75, is, with regard to the dimensions of the observed objects, as if it were in the centre of concentric spheres, upon the surfaces of which the objects, or their parts, are posited. If we suppose that two lines A B, A′ B′, which are equal, and situated in the same plane, form the chords of two great circles belonging to two of the concentric spheres, the radii A O, B O, A′ O, B′ O, comprehend two optical angles, the sines of half which are to each other reciprocally as the radii. Should the angles be equal, on the contrary, the chords A′ B′ and A D would be to each other as the radii.

2. With regard to the intensity of light, each point A, B′, B, B′, of any object, ought to be considered as a luminous body, (whether it is such from its nature, or only by reflection,) and, consequently, as the centre of a luminous sphere formed by a great number of divergent radii. The eye O is placed either at the point of contingency, or of intersection, of these spheres, which are osculatory when their centres lie in the same right line, and cut each other in the contrary case; the number of the divergent radii emanating from the luminous points, is in the inverse ratio of the surfaces of the spheres which they form; the quantity of light they project on these spheres, and therefore, that which is conveyed to the eye O placed at the point of contingency, or of intersection, of all the spheres, are in the ratio of the surfaces of these last, or of the squares of their radii; or, in fine, what comes to the same thing, in the ratio of the squares of the distances from the luminous points to the eye, since the surfaces of similar solids are to each other as the squares of their homologus sides: and as the dimensions of objects decrease in the same ratio as their distances from the eye augment, their surfaces diminish in the proportion of the squares of these distances; that is, in the same ratio as the intensity of light. Wherefore the surfaces and the intensity of light would have constant ratios, did not the density of air, and the variations in this

considering the intersection of the planes forming these summits, the azure of the glaciers, the whiteness of the snow, and the grayish colour of the rocks.*

In the same manner, although an observer may not be acquainted with the laws of sound and light, and able to calculate their velocities, yet he will, as the artillery-man, estimate the latter from habit. The intensity of the noise produced by a known cause will afford him the means of determining the distance of the object from which it arises, and hearing will sometimes serve him in rectifying the errors of his sight.

Lastly, habit enables us to estimate time, to find out the bearings of the place where we are, to determine our position on different spots, as well as the approximate situation of two distant places, without applying to these purposes the calculations and complicated observations relative to astronomy; but, merely by a simple knowledge of the principal constellations, and of the course of the sun and moon. Habit alone instructs the peasant in finding, at all seasons, the hour of the day from the altitude of the sun; a view of the constellations serves the shepherd during the night as a clock and a calendar, while he is in the fold in the middle of his flock: the Bear was for a long time the only guide of the first navigators: the inha-

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respect, disperse the radii of the luminous spheres, and weaken the light of the observed objects in a very complicated ratio.

These elementary notions may be extended from the perusal of the known Treatises on Optics and Perspective. I wish I could refer the reader to the Lectures on Lineal Perspective and Aërial Perspective delivered by *Monge* in the Polytechnic School; but these lectures are not yet published, although their publication is very much desired.

* For the particulars relative to mountainous countries, see the travels of *Saussure* and *Ramond* in the Alps and the Pyrenees, those of *Pallas*, &c.

bitant of extensive heaths, and the Arabian, wandering in the depth of night in their sandy plains, sit down and wait for the moon, or the stars, before they proceed further in their journey.

ARTICLE X.

Continuation of the same subject.

WHATEVER may be the forms of the various objects placed on the surface of the earth, Geometry values their dimensions, and enables us to conclude them from the very appearances which alter them: but have we no means of discovering these forms, except our instruments and our eyes? are they always different? do they not follow any law, and is there no analogy between them?

Let us examine if physical geography may be of any assistance to us, as other sciences are; let us investigate also the inductions which may supply us with general and simple notions, such as are consistent with the nature of this essay, upon the structure of the earth, and with regard to some atmospheric phenomena.

To him who contemplates the whole system of the universe, the earth, like the other planets, is a sphere which revolves round the sun, and turns on its own axis. Drawn towards that body by the attraction which it exercises, the laws of motion give it, on the contrary, a tendency to go from it; and as these two forces are in equilibrio, they retain the earth in the orbit which it describes: even the highest mountains are only inequalities hardly perceptible, when we compare them with the whole globe; they are scarcely to it what an asperity of a hundredth part of an inch would be to a globe of ten inches radius; but, if the earth be considered with respect to man, all its elements assume a much greater comparative magnitude; the ocean encompasses, as a vast girdle, the solid parts of the globe: these parts rise above the seas, and form continents, islands, and rocks; chains of mountains traverse each continent, and their summits resemble, at first sight, islands elevated above the plains; but a common and continued ridge connects their apparently insulated masses together; the principal chains throw out counterforts, that is, branches from which secondary chains proceed that produce other branches, and thus ramify *ad infinitum.*

These last branches, and the counterforts, frequently extend to sea-coasts; they become lower towards the isthmuses, rise again, form the ridges of peninsulas, and the projections of promontories, pass under the waters, show themselves by making islands, rocks level with the sea, shoals in the straits, and by rendering the structures of two opposite coasts similar. In this manner the ramifications of the continents are continued across the ocean itself.

These ramifications form a multiplicity of basins, which contain the courses of water of every description: the principal chains of mountains, and the great counterforts which separate the largest rivers, encompass, as a vast circular enclosure, the chief basins, which rise from the bottom as amphitheatres; a number of secondary chains and counterforts spring out from all parts of this enclosure, and prolong themselves by following directions leading nearly to the same point; torrents, rivulets, and other minor streams, run betwixt these chains and counterforts, which, after uniting two by two in common beds, flow into the sea through a single channel: thus the running waters offer, between the solid ramifications of the globe, other corresponding and intermediary, but more regular ramifications, of which the great rivers are the trunks; their branches spreading over the surfaces of the continents, and re-producing, but with varieties peculiar to them, the multifarious forms of vegetative substances.

Amphitheatres, similar to those previously described, encompass the gulfs and inland seas, as well as the lakes which have no outlet; and they discharge their waters immediately into them.

Continents are every where opposed by the ocean, straits by isthmuses, gulfs and inland seas by peninsulas; at all places, the general level of the seas presents forms full of resemblances, and announces an entire correspondence between the cavities and elevations of the solid part of the globe; analogies with islands are even perceived in lakes, and in the seas insulated in the middle of the continents.

In short, all the general forms of the globe display the effect of a single or principal cause.

We shall soon discover this cause, if we study by what admirable mechanism and continual circulation the waters drawn up from the vast extent of the seas, and either dissolved or suspended in the air, sometimes invisible, and sometimes forming clouds of all shapes in the vault of Heaven, come down afterwards in rain, dew, fog, and meteors of every description; and thus return, by following the courses of the principal rivers, into the seas from which the atmosphere had drawn them up. These rivers, the stagnant waters, and the wet ground, are also tributaries to the air, and restore to it part of the waters which they had received from it.

The sun, the wind, in short, every cause which may raise the temperature, or augment the pressure of the beds of the atmosphere, increases the property it has of drawing up the waters and holding them dissolved or suspended; all that cools the air, or diminishes its compressing force, prevents it from retaining the vapours.

Peaks, as well as the needles which form the summits of high mountains, powerfully and continually attract the clouds: the cold in these elevated regions throws them down in hail, snow, and heavy rain, and its intensity is increased by the glaciers and the accumulation of the snow: this last heaps up in the season when the sun is less powerful; and, although it afterwards acquires strength, yet the melting snow becomes hard, at a great height, from its contact with the glaciers, and thus adds new beds to their masses; wherefore the glaciers, as they are extended, encroach upon the lower ground, and uncommon heat only can bring them back to their former limits; but below this zone of ice, and even in the zone itself, the sun causes the waters to gush out; they descend in all parts from stage to stage, and form, as far as the plains, a continuation of lakes, cascades, and torrents.

A thousand accidents at once increase the quantity of waters, and multiply their ravages; vast heaps of snow, detached from the mountain by the heat and filtrations, slide or roll down its inclined sides, carrying with them fragments of rocks which stop the torrents: the snow, by melting in these last, augments the mass and the fury of the waters, which then break off all the obstacles opposed to them, and roll into the plain enormous wrecks, ravaging the meadows, and destroying the fields, plantations, and cottages.

Sometimes the waters of a lake suddenly burst the bank or the rock that separates them from the valley, and which they were undermining for a long time; their mass precipitates itself as a cataract into the adjoining torrent, and carries away every thing which the usual course of the latter could not draw along. This mass, augmented by all those which it envelopes, communicates to them its rapidity, and overflows the lower ground, where it washes away all the objects raised above its surface.

In high mountains, either old or recent traces of such ravages are every where found; analogous vestiges even announce irruptions still more dreadful, the remembrance of which is lost, in consequence of the long time elapsed since they took place, although the effects are yet seen. By considering the secondary chains and greatly depressed parts, which the summits of the principal counterforts offer to our sight in directions parallel to the axis of the primary chain, and if we also examine the considerable number of streams which flow across the parallel chains, between the vertical banks which their waters have worn in the rocks, it seems that masses of water and great lakes oscillated formerly at different heights in these primitive valleys, and only took their present course towards the plains, after breaking through the obstacles which formed their barriers.

Thus it appears, that, at that time, these masses of water forced themselves through the counterforts in some places, and carried away their summits in others, as is now seen; then, taking their course towards such parts of the ground as opposed to them a smaller resistance, they made their way into the lower valleys, which, at present, lead them to the sea. Their beds in these valleys become less broken, and form a greater number of windings, which testifies the slackening of the action of the waters, occasioned by their first efforts, a thousand successive obstacles, and by the facility with which they penetrated into grounds of a less hard nature.

We may attribute to this more regular action of the waters, and to their great masses in the first currents, the actual form of the extensive valleys where they remained for a long time; also the width of the secondary valleys, which now appears to have no relation with the waters flowing within them. Hence arises, likewise, the correspondence of the angles and windings which the sides of a valley and the banks of a stream inside of it, respectively form, as well as those smaller beds which a more feeble current has worn in the vast beds of the primitive ones.

The highest mountains have not, exclusively of the others, the power of attracting the clouds, and supplying the great rivers with waters, as heights of every description, forests, and plantations, exercise a similar attraction, which is the source of all fertility. But the waters in their more tranquil action filter through the ground; beds of clay stop them; they open subterraneous channels, form caverns, descend, rise again, and sometimes spout from the surface of the ground, being pressed by other waters descended from distant spots higher than the level of this last. In this manner they form sources, or fountains, that are wet permanently, or only at intervals, according to the abundance of the water filtering into them; and the nature of the beds which this water has traversed, renders it either cold or warm, pure, or charged with salts, or with gasses.

The clay land generally found upon the flat ridges of counterforts of an inferior order stops, even at the surface of the ground, the waters which the rain and the fogs have deposited there. Ponds, morasses, miry woods, and wet meadows, are thus formed, the waters of which, in endeavouring to run off, follow in small quantities even the least sinuosities of the ground, reach the edges of its flat parts, descend along the declivities, and unite themselves with the rivulets and other streams in the valleys, being sometimes tinged with a black or a blueish colour.

In fine, the waters arising from the rain which falls upon the declivities, run down along them, collect together, form ravins, which they gradually make deeper, and create permanent beds for these temporary torrents. The earth and sand that they carry away roll down suspended in the streams, augment them in their whole course, and trouble and tinge their water.

In addition to the rain which falls in the spring, dangerous occurrences are to be apprehended in many large streams from the effects of thaw, and of the breaking up of the ice; the melted snow comes down the hills, and increases the transient currents which spread about the country; the water runs under the ice of the streams, and, by swelling, raises it up with force: the ice breaks with great crashes; the fragments strike one against another, break and press each other: even the smallest obstacle, which stops their progress, causes them to rise; their sharp edges stand above the water, and as these fragments rest against each other, in an inclined position, they form a compact mass which exerts an enormous pressure; unless the inhabitants instantly open them a passage, or throw them into the meadows and marshes, nothing can resist them: dikes, bridges, sluices, give way, and their wrecks unite with the broken pieces of ice, which, as they float down the stream, menace other more distant works of man, the plantations, the villages, and even the towns on the banks.

Such are the periodic increases, on account of which even the most gentle streams, flowing along luxuriant valleys, may produce the disastrous effects of torrents.

Large rivers, the basins of which embrace several empires, change direction several times in their course, as if impenetrable mountains had originally compelled them to run back, and to seek for less powerful barriers.

A remarkable phenomenon takes place alternately upon each bank of these rivers, and upon those of their numerous tributary streams; they very frequently do not run in the middle of their basin, but follow, coast along, and even press against one of the sides: this side, which commands them, only pours torrents into them, or rivulets of which the course is very limited; the opposite side is far distant, and long branches project from it towards the river, which collect the waters of the principal streams, and convey them into this last.

The observation just made respecting the whole basin of a river is also applicable to its bed; the current follows the steepest bank, and keeps more close to it than to the other: flat banks indicate a gentle slope, and shallow water.

The opposite coasts of continents and islands exhibit similar effects also. The steepest coast, that which the current beats and undermines, generally affords the deepest anchorage: a coast which is flat, or gently inclined towards the sea, warns the pilot to sheer off, or to approach the shore only in small vessels.

We may easily represent to ourselves this general law, by referring the different declivities to planes differently inclined, and by determining mentally the positions and directions of the lines which are the intersections of these planes. With regard to the explanation of the effect, it is to be conceived that the waters were primitively contained between banks, which had not the same inclination; or, that one of the sides of the basin having originally opposed a smaller resistance to the waters than the other, the currents directed their first efforts against the masses on that side, which impeded their advancing; and as the declivity of the opposite side became more and more gentle as the former side gave way, the current was ever since thrown, with increasing force, against the steepest bank, which it still follows and undermines.

Where both sides of the basin opposed the same degree of resistance to the primitive currents, the course of the river follows the middle of it. Here this course is confined between vertical rocks, as between walls, and intersected by a thousand shelves, against which the waters dash: these last form whirlpools and abysses in the bed of the river, precipitate themselves from it in the smallest particles: this bed instantaneously disappears, gets ingulfed, and hides itself under natural vaults, or under blocks detached from the flanks of the adjoining mountain; further on, the river re-appears, in order to pursue its course tranquilly between hills which insensibly become lower; and sometimes, also, in the middle of a vast, low, and marshy plain, where it forms islands and peninsulas indefinitely varied: whilst the boundaries of its basin run a great way off, in parallel directions, the chains of high mountains which rise above them terminating the perspective view of the horizon.

Gradually as the river collects the waters of the streams which fall into it, and advances towards its mouth, the width of the valley augments, the ground on both sides becomes less inclined, and the heights which terminate it are depressed: extensive plains occupy the bottom of the basin, and elevated ones extend between the valleys in which other principal rivers are flowing; towards the points where the counterforts of high mountains meet the plains, other running waters take rise between the rivers, which have their particular bed and basin: similar currents flow into gulfs, or from the periphery of peninsulas, and form between the mouths of each two rivers a number of small basins, close to and independent of each other, which convey their waters directly into the sea.

These numberless currents, which, after originating in mountains, fall into the sea, follow declivities of which we may represent to ourselves the general curvature, by referring the bottoms of the various basins to a series of inclined planes, and simultaneously considering the action of gravity which carries away the waters, the resistance opposed to them by the ground, and the quantity of them which the upper currents convey, as well as their rapidity: if all these declivities be compared together, it will be seen that the whole system of the aforesaid waters descends from the highest parts of continents, by following a general and mean declivity, the inclination of which diminishes rapidly in the mountains, but becomes more progressive and uniform in the plains.

Were all the cavities of the globe filled up, a gentle and regular declivity would lead from the summits of the most elevated spots to the shores of the ocean; on the contrary, we remark in those parts of the ground which the action of the waters seems to have shaped, that originally rapid and then gentle and scarcely-perceptible curvature which characterises the general declivity of basins: we observe it on the declivities of small hills, in the traces and undulations which time, rain water, or tranquil overflowings have formed on the ground; and, in short, at all places where the waters had a moderate impulsion, and no great rapidity.

But, in high mountains, where torrents and snow even now direct incalculable forces against the rocks, we see the broken flanks of these last forming the sides of the valleys and gorges; and the same circumstance happens at all the points in which the hardest soil could only oppose an impotent resistance to the impetuosity of the waters.

Here no declivity is observed; but in this general confusion, the rocks of a different nature still assume forms peculiar to them, have their own physiognomy, and serve in characterising the ground. In chains of high mountains, granite almost every where pierces through the more tender rocks which it supports, and surmounts them; its needles and pyramids are distinguished by the sharp angles of their inclined planes, and by the form and brightness of the chrystals that compose it. These last sometimes are equally mixed, and sometimes varied; at other times they appear as if they were incrusted in one of the predominating substances: marbles and calcareous stones rise in steps over each other, in an amphitheatre, or resemble towers and steep walls: the beds or courses which form the elements of their whole mass are sometimes thick, and sometimes thin and leafy; in one place they lay in a direction parallel to the horizon, and in another they are perpendicular to it, or inclined in its respect.—In this manner they attest, so to speak, the successive disruptions which either sunk them, or heaved them up, during or after their formation: sometimes, instead of chrystals, we perceive an uniform and less brilliant substance, which has greater purity in the vicinity of granites, and is intermixed and almost entirely covered with shells as the rocks approach the plains. This substance evidently appears different from granite in its nature and the way it was formed; in short, every thing indicates that its formation arose from different circumstances occurred at different times, and is the result of new and secondary masses gradually applied to the primitive ones.

No doubt can be entertained of these aggregations having been successively produced by the waters, which, it seems, have several times new covered nearly the whole globe; but in other mountains, revolutions of a different kind are indicated: for instance, the smoke, the fire, and the torrents of lava, which gush through a crater, arise from a subterraneous fire which is not yet extinct; mountains that have the shape of a cone, the conoidical depressions of their summits, the scoria that is found about them, the lava which along their declivities rises in solid hillocks above the vegetable earth; all these circumstances announce extinct volcanos formerly the domain of fire, and ancient disasters frequently unknown to the cultivator himself, who gets in without fear his vintage and his harvest upon the same lavas which perhaps buried his forefathers.

The nature of the ground changes as we descend towards the plains; aggregations more rough than the preceding, imperfect rocks, brown free stones, *houilles*,* chalk, sand stones, and sometimes whole banks of pebbles, of gravel, or of shells, form the top of the ground, being only covered by an envelope of vegetable earth.

This envelope is the work of time. The wrecks of the three kingdoms, sand, silex, the *detritus* of vegetable substances, and even the remnants of some animals, composed the mixture of which it consists, and the hand of nature kneaded it by mingling together all the materials collected on the spot. These were scarcely sufficient in the elevated plains, where, for this cause, a single and shallow layer of this mixture frequently covers the sandy or stony ground.

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* A sort of coal.

On sloping grounds, this layer is gradually carried away by rain, and thus incessantly tends to disappear: the destruction of forests, the pasturing of herbs, and even culture, accelerate and favour the ravages of the waters: in high mountains the soil is washed away as the vegetables are removed; wherefore the rocks remain uncovered as far as the plains, and the bottom of the valleys; pieces of wreck descended from the mountains and forests, pebbles rolled down, gravel, trees, and the soil washed down, form a thick layer in the bottom of the basins, which covers the more solid base that supports it: a series of siliceous or calcareous beds, separated by beds of clay, organic remains, and vegetable earth, sometimes allow us to count the number of successive layers which formed them, and how many times new surfaces have exercised the vegetative power of nature which alternately repaired and buried her work.

The same effect continues as we descend towards the plains, but it is less rapid and terrifying than in the mountains, although equally constant. The rain and melted snow wash the hills, and deposit in the river the soil which they carried away; the river swells and overflows; its rapidity diminishes as its bed extends; the mud which it held suspended subsides, and these periodic alluviæ continually raise its bottom and its banks.

This movement, which precipitates into the valleys the wrecks of the elevated parts of the globe, either in a state of dissolution, or rolled down by the waters, forces the sea itself to recede from its shores, and to contract its limits. The natural or the accidental currents of it, the action of the flux and reflux of the tide, alternately slacken and accelerate the courses of the rivers and streams which flow into it, make their waters recoil, draw them forwards, stop them again, and, in the short duration of the equilibrium produced by the destruction of the forces acting against each other, compel these waters to deposit the solid particles which they are conveying; these particles, in virtue of their gravity, and even of the portion of water which unites them, resist the efforts of the other portion in order to disperse or dissolve them; and they form in the sea vast sandy banks, which successively rise above the mean level of the inland seas, and the various substances that the ocean casts upon its shores.

The inhabitant of the coast remarks this effect, and, trusting to his sole industry, dares to finish what nature has begun: he throws up dikes round these strands, from which the sea recedes for some instants; and although he is threatened within this enclosure by the water that surrounds it, yet he cultivates, with that idea of security which habit gives, a new and fertile ground soon covered with an abundant harvest; the rain water, and that of the rivulets, collect in the channel which he has made to receive them, and remain there until the reflux of the sea allows them to run off through the sluices which his foresight led him to place in the dikes, at suitable distances from each other.

Nature, assisted by time, entirely effects on some of the shores of the ocean and inland seas, what human industry only accelerates on others; it extends every day the *Delta*, which even the smallest currents form at their mouth, similarly to the largest rivers; and in order to defend its conquests, it calls the winds to its assistance, raising with sand booms and moveable hills which follow the contours of the sea, stop it, and protect against its fury the new border that nature has thus added to the continent.

In this manner, downs are the dikes of nature, and, like those elevated by men, indicate a territory which is aggrandizing itself at the expence of mountains and seas.

Forests which disappear, an alteration in the general directions of the winds, and other causes, sometimes modify this first order: the downs extend far into the country, cover the plains between the seas and the valleys in which great rivers are flowing, and present only vast sandy plains and arid deserts, where a few habitations, encompassed with some cultivated spots and plantations which defend them, rise like islands in the midst of the ocean.

The sea, which recedes from some points, resists and re-acts upon others, wearing away at these last the shores of the continents; steep beaches, perpendicular rocks, and shelves on a level with the water, attest ravages still more dreadful than those occasioned by torrents in mountains; we also observe on the coasts, in the straits of inland seas, and in the channels which separate continents and islands, traces of the irruptions which have burst the isthmus or the chain connecting the adjoining land in former times, and perhaps swallowed up vast countries and whole nations in those parts of the continent which were below the general level of the sea; the actual inhabitants of a territory conquered from the sea would perish, in the same manner, if the ocean were to burst the feeble dikes which are opposed to it in that country.

Such is the general structure of the globe; such are the principal characters and the most remarkable laws of nature which may guide an officer in reconnoitring a country, and enable him to conclude the principal forms of the ground from the courses of water represented in a map, as well as its most characteristic accidents from some rapid observations.*

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* For more comprehensive notions on these matters, see the works

This study teaches an officer in what directions the series of natural positions ought to be found, according as the country is flat, aquatic, or hilly; and it also conveys to his mind a notion of the kinds of accidents of the ground which defend the access to these positions, may support their flanks, render their rears more or less secure, and either prevent an army from being turned in its movements, or cut off in its retreat, or allow these disasters to take place. The same study teaches him, likewise, where he is to look for the point of separation of the waters in mountains, as well as for the fords and proper places for crossing rivers, establishing entrenched camps, and throwing up lines, or other obstacles, either permanent or temporary, which art may sometimes add to those afforded by nature.

Besides, if an officer, who possesses the above knowledge, survey a country, and particularly if he draw a map of it, the features of the ground will appear to his eyes merely as general forms with which he is acquainted; he is every where at home, while on the contrary, less-informed officers only see accidents always new and confused, which they have as much difficulty in discerning as in representing; wherefore, they are not directed by any remembrance or other guides; nothing surprises, stops, or misleads the former officer. He represents at all places, with that facility which habit gives, accidents familiar to him; he knows their characteristics as well as their peculiar physiognomy, and frequently foresees their existence before he actually

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on Physical and Geological Geography, as well as the general and topographical maps of chains of mountains, great basins, low countries, &c.

perceives them; thus he concludes from the objects within his view and reach, those which he cannot approach, and sometimes not even see. In this manner, for instance, he infers from a sight of the ground adjoining the banks of a stream, the declivity of these banks, the depth of the water, and in navigable rivers the road which boats or vessels ought to keep; in this manner, likewise, the sand and pebbles cast on the banks, the alluviæ, and other indices, make him aware that he is not to trust to the present calm state of the stream, or of the river, as they exercise periodical ravages, and may alternately suspend or favour the operations of armies.

These analogies guide an officer even in the details relative to his operation; they abridge his actual researches, and serve him as a compass to a navigator, in directing his course. In short, if they do not supply him with positive documents, they, at least, considerably increase his means of attaining them.

ARTICLE XI.

Last Remarks on the Method of Surveying by the eye alone.

THE reader has been shewn in what manner the courses of water offer, on the surface of the globe, a natural outline to which the forms of the ground may be referred; the wants of man have forced him to extend over that surface a net-work of communications, if I am allowed to use this expression, which intersect in all directions, the chains of heights, the plains, the valleys, and the waters.

The principal roads connect the capitals of states together, and also with the most considerable cities in the interior of the country, on the frontiers, and on the coasts; these roads proceed, as so many radii, from the centre of each state to its circumference. Other roads, like as many concentric circles, cut these radii, and form new communications between the cities traversed by the principal roads.

Each city, town, or borough, becomes in its turn the centre of other roads, which are directed to the villages and hamlets; a multiplicity of ways and paths commence from these roads, and serve in connecting them, or in affording convenient communications with the fields, pasture-grounds, forests, coal-pits, clay-pits, quarries, mines &c. as well as with insulated manufactories.

In high mountains, paths wind along the elevated parts on both sides of the valleys which they contain, run over the steps and ledges of the rocks, pass between the glaciers, and even in the midst of the snows, and reach the *cols* and depressed parts of the chains and counterforts, thus connecting the valleys contiguous to each face; most of these paths can be used only during some months, and they are frequently effaced by heavy masses of snow rolling down the mountains, or cut by torrents which are crossed upon a plank, a trunk of a tree, or upon rocks or stones that rise above the water.

Communications less numerous and direct, but wider, connect, across the counterforts and chains, the populous valleys where industry is carried on; or else, the neighbouring states: in some of them, mules only can be used, and in others sledges, or carriages may be employed: while the paths ascend or descend rapidly, these communications form such windings as render their declivity less abrupt; they sometimes follow the borders of torrents, and are cut through a rock that traverses the valley, or pass under an arch which it forms; sometimes too, parts of them are secured, under a ledge of granite, from the action of the falls of snow which destroy other parts, carry them away, or fill them with long trenches difficult to efface.

Roads in mountains sometimes commence only below the manufactories, and serve in conveying their products as well as the materials which they consume; stone, flint, the refuse of mines and forges, and even iron, are laid on these roads in order to make them firm, as the heavily-loaded carts, going along them without scarcely any interruption, incessantly tend to impair them.

As we descend towards the plains the principal roads become wider; they follow in their direction the elevated flat grounds, the bottoms of the valleys, and the declivities of the hills, traversing the basins and courses of water; rivulets are commonly forded, or passed upon planks, but larger streams require ferries, or either stone or wooden bridges; bridges of boats, flying bridges, and launches, are requisite for great rivers.

Most of these roads are stoned, or paved; but the materials used for making them firm, vary like the ground, and indicate the nature of the soil, which, in its turn, furnishes inductions relative to the degree of firmness of the roads.

The fascines and wooden rollers, which, in certain parts, line the sides and sometimes even the middle of a road, indicate woody marshes and humid forests; a soil that the summer sun has cleft, and stones, placed from distance to distance along the sides of the road, warn the traveller not to advance after rain in a clay-land, the apparent firmness of which will deceive him; the chains and stone posts, which he remarks in some countries on the sides of the causeways, warn him likewise, not to pass them after a heavy rain, or at least while it thaws; chalk, ditches sideways of the road which are filled with water, deep ruts, and other signs, furnish similar inductions. In the grounds conquered from the water upon sea-coasts, in clay-pits, and salt-marshes, the dykes themselves are used as causeways, and only serve for that purpose in fine weather; in heaths and downs, roads which are not lined can only be distinguished from their surface being more trodden than that of the lateral ground; nay, the sand, which the wind carries from this last upon the roads, sometimes makes them disappear, or intercepts the communication along them; but upon the shores of the ocean, as the beach is hardened by the waves, it offers at low water, between the tides, a smooth and firm road practicable even for carts.

A cause-way elevated above the valley which it follows or traverses, planks laid down here and there, small sluices, and a series of arches apparently useless in common times, indicate that this communication is occasionally threatened by the swelling of the waters; where fore we should observe, if the aforesaid openings are sufficient for their flowing out, or if it appears from the decayed state of the tops of the arches, of the supporting walls and the foot-paths, and from other indices, that the waters sometimes overflow the cause-way.

Cross-ways and by-ways, although less firm than the main roads, have characters analogous to them. It is particularly important to examine whether they serve as communications between these last, or between inhabited places; or, if they lead, on the contrary, to fields, woods, or marshes; their directions and smaller degree of firmness, the bridges across them, the ditches sideways of them, their ruts which are less deep and numerous, still offer indices in their respect, which may serve in reconnoitring them. These ways frequently cross a multiplicity of fords where the water scarcely rises above the feet of a horse, but a ferry-boat, or a bark near a cottage, the elevated spot upon which this cottage stands, a bridge, a plank laid over tressels, or tressels ready to receive it, indicate a temporary ford which the swelling of the water changes into a deep and frequently-dangerous bed.

Foot-paths, less fatiguing and perilous than those of the mountains, wind, as by chance, in the valleys, on the sides of the hills, and on the flat elevated parts of the ground; they connect the cross-ways, and intersect the country in all directions, several of them extending to marshes, woods, and thickets. Foot-paths are very frequently known to the inhabitants only; wherefore a traveller, who is not acquainted with them, finds it difficult to follow their directions: they cross each other, and often disappear; but houses, a plank laid across a ditch, or a pole which serves in leaping over it, a bush stripped of its leaves or broken, the grass which is pressed down or discoloured, the corn which is slightly laid, and a thousand signs imperceptible to other eyes, will point out the way to an observer who attentively considers all these particulars.

The various courses of water, the navigable canals, and those intended for irrigation and drainage, trace additional lines on the surface of the ground, which guide us in observing and describing it, and form, so to speak, new connecting points in the outlines of the roads and waters.

Even upon the tops of mountains, the shepherd draws from the torrent a small stream which he conveys through his pasture grounds by more gentle declivities: this new rivulet forms a thousand windings; a slate, or a piece of board, serves for a sluice; and the shepherd stops at pleasure the course of the rivulet which thus swells, overflows, and falls again, in a sheet of water, into the branch of the torrent below it.

Other places may not admit of this ingenious contrivance for want of a proper declivity; but then the rivulet is divided into several branches, and small trenches conduct it, in all directions, to the foot of the hill. Such is, for instance, the method used in certain countries for watering and bleaching linen cloth and some other manufactured goods.

Sometimes a small stream, drawn from a torrent or a rivulet, and commencing a great way off, follows in a bed purposely dug, or contained in a wooden trough, the side of a mountain or of a hill, while the torrent, or the rivulet, from which it is derived, flows at the bottom of the contiguous valley. This small stream conveys to manufactories the motive force which sets in action the machines appropriated to them; and then it returns, by a small channel, to the natural bed which it had been made to quit.

When the fall of the water is small, and the original stream of a certain magnitude, whole branches must be drawn from this last, for the convenience of manufactories. These branches continue to flow inside of the valley, but generally close to the hills which terminate its breadth; wherefore, a single dyke is requisite in order to retain the water.

At other times, these branches flow between several dykes, along the natural bed of the current; this bed is also often cut in two, or divided by a dyke parallel to one of its banks: a separate column of water is thus contained between the dyke and the bank, which runs less rapidly, and imparts motion to the machines of the manufactory situated lower down, at a point where the difference of this artificial and the natural declivity affords a sufficient fall.

More frequently a dyke is thrown across the stream, which causes the water above it to re-flow and swell: dykes of this kind augment the falls, and allow the manufactories to be nearer to each other, but they render the valleys subject to be inundated, whenever the water is somewhat increased. Sometimes the multiplicity of manufactories induces the inhabitants to confine the stream between dykes, in such a manner that the water rises over the bottom of the valley; and similar dykes have also been constructed in some countries, in order to prevent inundations. Towards all the points where streams begin to be navigable, and to allow the timber cut down in mountains to be conveyed to the plains by water, as well as the products of the manufactories established in the upper valleys, dykes and pentroughs of this description cross their beds, and support the water at such height as navigation requires.

In these rude works, such as they were originally constructed, man has consulted his wants more than nature; almost always a single channel opens to boats and floats of timber an insufficient passage for the efflux of the waters in floods. The manufactories, while standing still, only afford a similar passage, and the waters flow in a thin sheet over the remainder of the pentrough; their velocity varies from the bottom to the surface; the mud and rubbish accumulate along that side of the dyke which faces the current; while, on the other side, the fall of the waters deepens the bed, which thus has a constant tendency to change its natural declivity from one pentrough to another, and the deposit to form interposing banks in contrary directions. The mud which the current carries along, at the time of the waters increasing, subsides between the dykes thrown across the stream, when their impetuosity is abated: the bed thus rises, and the dykes must be made higher: besides, the waters, particularly when they are much increased, accidents, moles, and insects, impair the dykes, which, therefore, fall to pieces, or, at least, allow part of the current to filtrate through them; and as the waters arising from these filtrations and overflowings are slackened in their course, as well as the tributary rivulets and the rain water descended from the hills, by the greater elevation of the bed which ought to receive them, they change the meadows on the banks into marshes, where a multiplicity of very small streams are seen, which have no apparent course, or which slowly descend along the main stream until they find an outlet. In summer time, the inhabitants seek for fuel in these marshes, make turfs of the upper part of the ground, dig clay-pits at random, and render the valley completely impracticable.

But a more cautious industry sometimes prevents these disasters, and provides for every thing; it abandons the bed of the stream to navigation, substitutes for dykes bridges with sluices, and constructs reservoirs along the bed, or digs particular channels, for the overflowing waters, at all the places where the sluices require that the space between the banks should be contracted. In these sluices, flood-gates and locks afford a wide and deep passage to the waters, which extends to the bottom of the stream: clay pits are regularly formed on both sides; a multiplicity of channels, crossing each other at right angles, drain the marshes, and convey the waters of the tributary rivulets, as well as the rain water descended from the hills, into ditches which follow the direction of the principal bed, and receive also the superabundant water of this last. Every year, when the water increases, the inhabitants throw the stream into these marshes, channels, and ditches, where it deposits the mud which it conveys; they then cleanse it, as well as the tributary rivulets, cut the reeds, remove the slime, and use it either in rising the soil, or in fertilising it: at other places they apply the same process to natural marshes, and construct basins wherever channels are insufficient; they change the pools formed by clay pits into ponds and productive fish-keeps. These ponds and fish-keeps, the stream and its tributary rivulets, as well as the channels and ditches, meet and intersect each other; thus dividing the ground into a variety of meadows, cultivated fields, and gardens.

Such are the modifications, respecting the natural course of the waters, which manufactories, drainings, and navigation, require at many points.

Canals serve in connecting basins, rivers, and even seas; here they ascend and come down hills, between locks frequently close to one another; there they cross ravins and rivulets, in the shape of aqueducts; further on, streams and canals of a different level traverse them, and intersect each other between two locks: in this space, the depth of the water changes, the water is thrown from one bed into another, and a passage alternately afforded for the currents and boats, by means of four sluices which may be shut two by two, and opened at pleasure: basins, placed on elevated flat parts of the ground, collect the waters which navigation, the manœuvre of the locks, and the incessant filtrations and evaporations require; a rivulet, the bed of which is higher than that of the canal, a lake, or a pond, situated on an elevated spot, supply these waters; channels convey them down from various distant sources, and sometimes, too, the bed of a river standing higher than that of another, the former supplies alone the canal which connects it with the latter.

Hailing ways frequently form a double communication upon the dykes and banks of the canals and streams; wherefore the vessels that carry troops and ammunition, and those which it may be requisite to collect for some military operations, may be rapidly drawn by men, or by horses either walking or trotting.

Such are the works in which art frequently struggles with nature, modifies, transforms, and bends her to our wants: sometimes impotent in its means, blind in its purpose, and fatal in its results; but sometimes, too, superior to all obstacles, preventing every accident, and sporting, so to say, with the elements, of which it is the master. A knowledge of these works not only furnishes a multiplicity of inductions respecting the nature and form of the ground, but the communications by land and water, which it is so important to consider in military operations, have infinite relations with the situations of the following objects that still remain to be treated of.

The courses of water, as well as the navigable streams and the roads, determine the situations not only of the insulated manufactories, but also of the villages, manufacturing and commercial towns, and particularly of the fortified places and posts: besides, there is frequently a remarkable analogy between the form of the ground and the inhabited places; near a stream, the villages extend along its banks, and are divided by streets, parallel to the current, which smaller streets leading to the stream intersect; while upon the hills and the flat elevated parts of the country, the villages are placed at the crossing of the roads, and the streets formed by these last: the houses line each side of the streets, and narrow lanes, distant from each other, separate them. If the village have a certain breadth, the main streets are frequently parallel to the roads. An analogous distribution is observed at all places where a road crosses a stream: if the former be the chief communication, it determines the disposition of the principal streets, which, on the contrary, follow the banks of canals and navigable streams: the houses face these streams and canals, and gardens enclosed with walls, or more frequently with hedges, separate them from the country in their rear. These gardens have, in general, an irregular form, but their size is almost always proportionate to the extent of the habitation to which they respectively belong. The same causes influence the plan after which towns and cities are built; they chiefly occupy the points where several streams meet, or those where a stream divides itself into branches. We particularly observe in the contours and streets of old towns and fortresses, turnings and angles which correspond to the windings of adjacent streams, and to the angles formed by those which fall into each other: and this correspondence is even seen, to some degree, in modern towns, where art has subjected the ground to a more symmetrical arrangement.

Other relations may be easily perceived between the positions of the villages and towns placed upon the declivities of hills, and the depth of the inundations to which the lower ground is subject; and also, between the tides and the elevation of the spots where the villages and towns along sea-coasts are built: on all sides, relations of another order strike our eyes, and enable us to conclude, either the ground from the constructions raised upon it, or these constructions from the ground; nature every where marks out the limits which man ought not to overpass, and supplies him with the materials requisite for his works.

Vegetation and natural products, as well as those of agriculture, clothe, colour, diversify, and ultimately characterise the surface of the earth. Maps only distinguish the principal woods, meadows, and cultivated lands; wherefore reconnoitrings, the sole object of which is the construction of maps, require but a small number of details that a glance over the country will give. We shall have an opportunity, when we treat of Descriptive Memoirs, of considering the aforesaid brilliant dress of the surface of the earth in another point of view, and observing the analogies which it every where has with the nature of the ground, the waters, the roads, and the inhabited places.

Thus all the objects which require observation are connected with each other; a thousand relations assist the observer in seizing and finding out a multiplicity of these objects, one by means of another, and therefore guide his steps, his eye, and his pencil.

ARTICLE XII.

On the drawing of Maps relative to Reconnoitrings.

We have treated of the instruments, processes, inductions, and general means of observation, which may assist an officer in reconnoitring a country; in determining, verifying, and comparing together the triple outlines of the triangles, waters, and roads; and in referring to these outlines the works of man, as well as the general forms of the ground, and every remarkable object which the surface of this last presents. But, gradually as the observations are made, the results should be transferred to a map, and fixedly expressed by a graphic description of the ground, combined with a drawing at sight of the particulars of it, and with the hand printing and signs generally adopted.

A Committee, composed of engineers, and other officers interested in the progress of Topography, has lately determined the means of drawing maps with as much perfection and uniformity as can be attained;* and the results of these officers' labours are found in the 5th number of the *Memorial Topographique et Militaire*, where the Committee unfolds, in a more extensive manner than this essay admits of, the principles to be followed in the projections, the representation of the ground, the conventional signs, the hand printing, and even in the size of the maps.† Maps and other specimen of all kinds, executed by our most eminent Topographers, connect example and precept; I shall, therefore, refer the reader to that important work, and satisfy myself with making in this place some observations peculiarly applicable to the method of sketching ground on the spot, it being the only one which in many cases may be used for maps relative to reconnoitrings.

Even in this method, time and the means which we can command frequently allow us only to represent, by a single line, the courses of water and the roads, as well as the most remarkable forms and principal accidents of the ground; the delineation of the objects terminated by planes or other surfaces cutting each other, is given by the projections of their edges, and with regard to the undulations of the ground, (the surface of which is a continued curve,) their representation consists in the projections of certain lines supposed to be drawn on their surfaces. The Committee previously mentioned has explained in the *Memorial Topographique et Militaire* the reasons which render preferable to all other lines those indicating the curves which a drop of water would describe in coming down the various declivities.* At all events, the projections of these lines, as well as those of the apparent contours, or of the edges, most frequently give curves which cannot be valued, or that we can only refer to other curves the laws of which are very complicated: few of the determinable curves admit of being described by a continual motion, according to methods more or less simple; the circle is the only one that can be speedily traced by an easy and convenient process, and even this figure will not afford such advantage, if an arc is required the radius of which is very great with respect to the plane where it is to be described: every other curve can only be determined by means of points which equations give in geometry, and are obtained in surveys from the summits of the triangles, and from the intersections or the prolongations of the outlines which guide the observer.

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* Government had appointed the author a member of that committee.—*Translator.*

† I beg leave to refer the reader to my Work entitled, INSTRUCTIONS FOR OFFICERS IN MILITARY PLAN-DRAWING, where he will find a variety of specimens relative to the description of the different parts of the ground, the methods of enlarging and reducing maps, &c.—*Translator.*

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* Most of the present Geographers and Engineers follow this system, and, in order to apply it, we ought to represent mentally to ourselves the curves which drops of water or other heavy bodies would describe, by virtue of gravity, in coming down the various surfaces which the undulations of the ground present: we should also determine by sight the projections of those curves, and use them in designing the various curves of the heights, of which they represent, in all directions, the steepest declivities.—*Translator.*

But these points, which in theory are supposed to be sufficiently numerous, that the lines which connect them may not differ from the corresponding portions of the curve, are limited in practice, with respect to their number and positions; they do not actually give the curve, but only a series of right lines, or, which comes to the same thing, the sides of an inscribed polygon: therefore, it still remains to draw the curve through the vertices of the angles formed by these sides, and to describe it in such a manner, either by trials or otherwise, as to be free from indentures or breaks in the curvature: thus the tracing of curves, in this instance, is connected with the method of sketching ground on the spot, and its analogy with it is so much greater as the guiding points are less numerous and more irregularly situated. These points undoubtedly assist the Draftman, but it is not less requisite that his eye and hand should be accustomed to the process: indeed, habit in this respect may not be so much wanted in operations which are performed at ease, as the observer, if he have patience, can multiply the guiding points at pleasure; but great facility in imitating all kinds of curves is no where more indispensable than in maps relative to reconnoitrings, as the guiding points are generally in small numbers and inconveniently situated. Besides, the projected curves are frequently to be determined and described from sight alone, and the observer, who almost always can only represent the objects by their outlines, must find all the means of expression in these lines.

It follows from what has been said, that an officer, who wishes to be employed in reconnoitrings, should studiously apply himself to figure drawing, and particularly to the drawing of antique statues, as, by that means, he will work after specimens of the most graceful and difficult outlines which it may be attempted to imitate. Experience has shewn that this kind of drawing is the foundation of all others, and that a Draftman, who is properly acquainted with it, has no difficulties to apprehend in any other kind.

The striking analogy which the drawing of maps has with figure drawing, is not confined to the various and sometimes so graceful curves which the courses of water and the undulations of the soil describe, as it extends even to the methods used in both these kinds of drawing. The reader knows that masters who teach the rudiments of drawing refer to known curves, or to given right lines, the projections and contours of the human figure, of the head and all parts of the body. By measuring antique statues, Audran, Le Poussin, and others, have regulated the proportions of that figure, and derived, from one sole module, or from its divisions, the dimensions and relations of the axes and other right lines which serve in determining the contours: painters, in short, similarly to geometers, have sought the co-ordinates of the curves of the human body; but these lines, which greatly assist beginners, are for the consummate artist only means of verification, and cannot supply the place of taste and *coup d'œil*, which alone should guide him. Time, if not taste, prescribes laws nearly similar in the drawing of maps; every thing must be sketched at sight in reconnoitrings, and regular surveys terminate in the representation of the ground: in all cases, imitation is the ultimate purpose, and then Geometry forsakes the observer, who, therefore, no longer finds resources except in drawing. Thus, in this kind of work, as in all those of man, arts, apparently unconnected together, assist each other, and realize that allegory of the ancients who made the muses sisters and companions.

The art of sketching outlines properly should be the first study of an officer ; next, he ought to draw and shade from a bust, or any other model of this kind, as his knowledge of the effects of light and shade, and his practice in that respect, will prove of great utility to him in representing correctly, over the outlines, the relief and forms of the ground. The Committee for the improvement of Topography, of which I have previously been speaking, has unfolded these views, and decided that perspective, the laying of tints and shadowing, shall form part of the applications of physics and descriptive geometry taught in the *Ecole Polytechnique ;* and that the instruction given to the students in this fine establishment shall comprehend figure-drawing, and drawing from a bust, or any other model of the same description, as aforesaid.—Indeed, it is not so much requisite that an officer upon the staff should be a proficient in these two kinds of drawing as an engineer, since he may perform his duty with credit to himself without such a knowledge. But he will undoubtedly reap great advantages from possessing it : the habit of handling his pencil with ease and lightness will enable him to express quickly that multiplicity of windings, contours, and curves, indefinitely varied, which the courses of water and the undulations of the soil present ; he will also have many opportunities of congratulating himself on being able to impart to hasty projections the accuracy of more deliberate operations, and in simple sketches, to observe that correctness of form and expression which preserves the physiognomy of the objects, and helps the general officer in distinguishing them on the ground. Besides, I shall remind the reader of the assistance which a knowledge of drawing gives to an observer, in appreciating the merits of the maps from which he derives the outlines of his work ; in rectifying the judgments of his sight, when he surveys by the eye alone: and in concluding, from the tints and optical magnitudes, the distances, forms, and even the colours of the objects. In short, although this knowledge may, strictly speaking, be considered as a secondary acquirement which is not indispensable for reconnoitring, and cannot supply the place of the other qualifications required in that branch of service, yet if one of two officers, who are equally qualified in other respects, is properly acquainted with drawing while the other is not, the former will undoubtedly surpass the latter in point of accuracy and expedition.

ARTICLE XIII.

On Descriptive Memoirs.

Descriptive Memoirs may answer various purposes.

They sometimes supply the place of maps, by giving merely a written description of the objects which maps should actually represent: this happens whenever time is wanting, as, for instance, when a short reconnoitring, rapidly performed, does not allow any sketch to be drawn; and also, when it is deemed sufficient to describe in writing such particulars as would take too long in drawing. What has been said respecting the surveys performed by the eye alone, is equally applicable to the reconnoitrings made for the purpose of laying down descriptions of this kind, the proper digesting of which is perhaps more difficult than drawing: it requires at once, from the author, imagination, *coup d'œil*, and memory; and the style should be such as to exhibit to the mind a picture, as it were, of the objects described.

Officers may consult in this respect approved memoirs, but discriminately; and they should also be aware, with regard to the drawing of maps, that war requires no landscapes: the country is not to be described under one point of view only, but under all aspects; it being represented such as it would appear to an observer hovering over it, and in reference to war, which is the sole object of his labours.

The purpose of a Descriptive Memoir may also be to exhibit, in a different point of view, or in a more commodious form, some of the particulars which a map represents.

An account of a country, written in a general way, may, if it be well executed, give additional clearness even to the best map; it elucidates the most important particulars of the ground, and shows, at one view, the obstacles and the conveniencies which the soil, the waters, and the roads offer.

It is highly useful to indicate summarily in separate sheets, corresponding to the maps, the manner in which the rivers are intersected by their principal and secondary tributary streams, as well as the disposition of the principal and secondary branches of the mountains with regard to the chains. By this means, the connection and relation of those numerous ramifications are shewn under a new form and a nearer point of view.

It is not less important that the communications by land and water should be described in similar sheets, as well as the defiles, bridges, ferries, and fords, situated in their directions; and that the distances between all these points should be marked.

Even supposing that these sheets do not contain any other objects but those which are expressed in the maps, yet they facilitate researches, and form a kind of separate legend. They may also answer another purpose, namely, that of presenting under the heads of columns of observations the remarks made during the survey, but which cannot be explained in a map, respecting the nature and particular accidents of the chains of mountains, courses of water, and of the communications.

The sheet in which the roads are described may also contain such notions respecting the distances, as a map cannot convey: even supposing a country to be accurately surveyed, and the distances marked with as much exactness as circumstances permit, time may be wanted in order to calculate them. Indeed, maps are frequently far from possessing such a degree of perfection and correctness; an officer cannot measure all the roads, and, in many cases, he is obliged to trust to the inhabitants, or to the guides whom he takes in the country: nay, in order to profit by the information which he derives from them, he must know the values and relations of the itinerary measures used in the country where he operates. Comparative tables of these measures are absolutely necessary for him; but, although he may have some, yet he ought not to dispense with questioning the inhabitants, or his guides, on the values which they ascribe to the measures of all denominations: these values and denominations often differ from the legal values and true names, and sometimes present, under the same name, quantities which have no relation with each other: in certain countries, the extent of a league changes as we pass from a province, a district, and even from one village to another, while one hour's walk expresses, in different places, distances which vary as the character of the inhabitants and the nature of the ground; in short, as the space which in a given time may be passed over with different velocities depending on the kind of ground.

Comparative tables of itinerary distances are then materials which officers should consult and complete; this is what the performers of the best military reconnoitrings have done: it is highly important that the *Depôt de la Guerre* should collect these results, and publish successively, in the Memorial, tables of itinerary distances which may guide the officers, diminish their labours, and turn their own researches to the good of the service. These tables would also serve as models for those which officers may be obliged to construct when war is carried on in a new country.

There are still other notions which maps cannot give, and which constitute the chief object of Descriptive Memoirs; I mean those which relate to the climate, resources, population, customs, and to the administration of a country, considered in their relation to war. Here descriptive memoirs are no longer supplements to maps, but have their own independent character; if the reconnoitrings performed for the purpose of constructing maps may also serve in digesting memoirs, and the observations be simultaneous, the officer must follow other rules, embrace a more extensive plan, and resort to new means of observation.

From the most elevated parts of the continents to the sea, the relative heights of the ground influence its productions, and, under the same latitude, transform, as it were, the same climate, into a series of different ones; mosses and lichens live under the glaciers, and alone resist, towards the pole, the rigours of perpetual winter; lower down, a few shrubs continue the chain which, in the vegetable scale, connects the mosses and the resinous trees. The forests of the north cover the flanks of the mountains, and protect them from the torrents, as well as from the rolling down masses of snow: the hunter pursues the chamois among the rocks; the gorges which these last encompass, and the ridges of some chains of mountains, produce a short but excellent grass, upon which the flocks feed during summer. Goats climbing the rocks in quest of pasture, and a few wooden buildings where cheese is made, indicate the temporary abode ofshepherds ; upon the borders of the lakes below, and towards the pointswhere the rapidity of the torrents diminishes, the meadows commence under the protection of the forests; the waters flow amidst a more fresh and vivid verdure, and the shepherds reap on these spots, which are not far distant from the hamlets and villages, the requisite forage for their flocks in winter. Such are the mountains inhabited by a pastoral people, the natural state of which has not yet been changed by clearing the ground, or on account of the great consumption of wood which some manufactories require. The pastures, flocks, and population, frequently bear such proportion to each other, as scarcely allows the inhabitants to derive sufficient means of subsistence from the produce of their flocks, while, in other places, this produce exceeds their wants. In these places, a less wretched life, even a kind of luxury relative to their situation, and a few mules or other beasts of burthen, indicate the beginning of a commercial intercourse between them and the inhabitants of the plains : from these indications, an army may rely upon finding some resources on the spot, with regard to provisions and means of conveyance ; but prudence requires that the supplies should first be drawn from the depôts, and that the provisions which the country can afford should be preserved for the frequent cases where the communication in mountains is suddenly interrupted : it is particularly proper that the soldiers should spare the flocks, as, without it, they would deprive themselves in one day of a constant resource, and reduce to despair a population which is almost always courageous. In countries of this description, another care ought also to engage the attention of the heads of the army, as the fuel for the troops requires a great quantity of wood, and it is material to consider what are those parts of the forests which admit of being cut down. Indeed, a cluster of trees frequently protects a road, a meadow, and even a village, from the heavy masses of snow rolling down a mountain.

Sometimes the inhabitants derive their easy circumstances from a source of industry unconnected with the keeping of flocks, and apply themselves to it during winter. This industry ought not to be overlooked in the reckoning of the resources which the country can afford; at all events, the difficulty of finding sufficient provisions and means of conveyance is the greatest obstacle to the stay and movements of troops in these high valleys, where a pure air, a salubrious climate, the impossibility of living to excess, and the exercise which even short marches afford, keep the soldier in an habitual state of good health and vigour.

A total change takes place when, instead of flocks, manufactories are established in mountains, and the allurement of gain precipitates into mines the inhabitants of the high valleys; particularly if the forests are ruined on account of the great consumption of wood which ironworks, glass-houses, &c. require. Indeed, a few more animals and means of conveyance are found in the country, but it only affords a scanty quantity of provisions, and sometimes none at all, as the inhabitants themselves are supplied in this respect by those of the plains.—Here pits, rubbish, and a small number of badly-cultivated gardens and ragged meadows, announce a people who seek their livelihood in the bowels of the earth; further on, charcoal is brought down the mountains, as well as timber, rough or squared, cut for burning, or worked into beams, planks, and light vessels. By degrees vegetation disappears, and fuel becomes very scarce; the naked rocks reflect the rays of the sun, and the valleys are open to all winds; the marches of the army are more fatiguing, the bivouacs more hard, and the war is carried on with greater difficulty.

But if it be perceived, on the contrary, that the forests in the vicinity of the manufactories are spared, the meadows more rich, and that the ground at large is better cultivated, this circumstance indicates that pits of *houille*[*] are not far distant, which supply the manufactories with fuel, and the soil with manure.

Vegetation, which is at all places relative to the climate, changes, in high mountains, according to the various aspects, the directions of the different valleys, and is also affected by the directions of the heights on both sides of the same valley; the periphery of a mountain of this kind, the opposite sides of a chain, and even the declivities which face each other, present the contrast that we observe in the climates of the north and south countries; while one of the opposite sides abounds in rich pastures, the cattle find no food on the other, and are therefore compelled to seek their nourishment beyond the *cols* and the snowy spots. In the depressed parts of the Alps, and in those where the climate is warm, we frequently see vine and orange trees follow immediately the forests, or cover the opposite side to that which these last occupy. Thus such or such position, and sometimes only the breadth of an intervening torrent, decides whether an army will live in plenty, or be subject to want.

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[*] The reader has been told that *houille* is a sort of coal.

Below the summits of high mountains, a vast number of counterforts and elevated flat spots is occupied by forests, heaths, morasses, and half-barren patches of tillage; the valleys which divide these spots and counterforts, are narrow, uncultivated, and impaired, in consequence of an ill-established navigation, or of the manufactories situated within them; wherefore, they often present only meadows or marshy grounds, which are little productive; the country is destitute of resources, easy communications, and nearly of all means of conveyance; it is also unhealthy, and, should an army traverse it, the troops will not be able to resist the influence of the climate, unless they frequently march and encamp, and have numerous fires lighted up in the bivouacs, in order to counteract the dampness of the air and soil; it is requisite, likewise, that the soldiers should be supplied with restorative food and beverage.

As the flat spots just mentioned become less elevated, and the width of the valleys augments, the population, inhabited places, industry, and the resources of all kinds, increase in rapid progression; the banks of the streams and rivers, those of the canals and the sea coasts, favour not only agriculture, but also manufactories and commerce; the climate is more salubrious, likewise, on account of the ground being better cultivated; only, near such coasts as form the boundaries of a territory conquered from the sea, the frequent interruptions in the efflux of the waters, the mud of the ditches which is left uncovered after the sluices have been opened, in short, a low and damp soil covered with fogs, give rise to epidemic diseases, from which the inhabitants themselves are not free; their paleness and whole habit of body testify their weakness and sickly state. Indeed, even the higher parts of the countries just described require, similarly to any other country, and particularly during the heat of summer, that the spots where the troops are to encamp should be chosen with precaution, as well as the water for their use, and that means should be sought for purifying the water, if it be unwholesome; or at least, for counteracting the effects of its insalubrity; the rains of autumn, and the proximity of vineyards in the vintage season, also prescribe peculiar dispositions for preserving the health of the soldier, and maintaining strict discipline among the troops, when they are either marching or halting; the choice of the roads and bivouacs requires consideration likewise; but, with the exception of these precautions, every thing favours war in those countries, and the principal object there, is not so much to seek resources, as to use with prudence those actually at hand.

In countries, overrun with heaths, as well as in downs and sandy plains, the army will meet the same difficulties as in high mountains, with respect to provisions and means of conveyance; besides, it will suffer from the want of wood and water, and from the insalubrity of the stagnated pools; without speaking of the heat in day time, and of the dampish and unwholesome vapours of the night; the inhabitants, who are either shepherds or ramblers, and live, the former on the produce of small flocks, and the latter by the chace or rapine, will supply the army with but few provisions, while they will frequently oblige it to march in order of battle, and to secure the camps and quarters by numerous posts or by defensive works. Thus in a country, provisions, the means of conveyance, and all other resources, have remarkable relations to the nature of the territory.

But it is not sufficient that these analogies should be known, as the quantities of the various objects which the country affords must be computed, and that part of them determined which may be properly applied to the wants of the army.

In our own country, these documents may be collected beforehand, and ought to be the subject of military statistics which, in a defensive war, would prove highly useful by affording the means of levying all kinds of contributions in a more just proportion.

But these documents are at once more requisite and less easily procured, when the army is actually upon the offensive, or preparing for it. The first fruit of victory is to throw the whole burthen of the war upon the enemy, and to live at his expence. In our own country, a regular administration and some fixed regulations direct and facilitate the collection and distribution of the provisions, means of conveyance, and of the supplies of all kinds which an army requires; but, in the enemy's territory, a thousand circumstances occasionally prescribe to modify the established rules; to give to the soldier provisions different from those which he usually receives, or to alter the quantity of these last; finally, to assimilate his food to that of the inhabitant who lodges him, and substitute certain eatables for others. It sometimes becomes requisite likewise, to consume the whole of the provisions, to put all the means of conveyance in motion, to employ a great number of inhabitants, and, in short, to use every resource; wherefore, none should be unknown.

It is scarcely possible that an accurate estimation should be made of the resources which either our own territory or that of the enemy presents, except from documents previously collected under the direction of government, or of the local authorities; such are the registers of lands, and the statistics of the country. Indeed it frequently happens, that a province, or a district, having made an arrangement with the sovereign for the taxes, has its own register accurately drawn up, while the remainder of the state has no basis upon which the assessments may be laid. The first proceedings of an officer should, therefore, be to ascertain if there is such register, or if, at least, materials have been prepared for the purpose of making one; and, after procuring these documents, he ought to consult them, to make extracts, and to insert the results of his investigations in the Descriptive Memoir which he is about. Should no register of lands be at hand, the lists for the assessment of taxes, the records of the Custom-houses, some statistical memoirs, and other documents, may give information, or, at least, furnish indications, respecting the provisions, sums of money, means of conveyance, and other resources, which the country can afford. Imperfect as these documents may be supposed to be, they will at least answer the same purpose with regard to Descriptive Memoirs as is attained in maps relative to military reconnoitrings by supplying with outlines the officer engaged in the operation, before he has begun it.

When the above means of investigation cannot be procured, the magistrates on the spot, the well-informed people, and particularly the old men who have been witnesses of former wars, will supply the place of them, and give a multiplicity of details which may be relied upon. But there is much art wanted in collecting documents in this manner; authority, fear, and violence, with difficulty draw forth unconnected confessions which perfidy or fright may render unfounded. Indeed, this method of obtaining the information wished for, is sometimes requisite because every other has failed; but it should be employed only in such circumstances. An officer will succeed best, if he appear not to demand any thing in his official character, but contrives, under various pretences, to introduce himself naturally to the persons who are able to instruct him, and to learn from them, by way of conversation, the particulars which he wishes to know, without putting to them any explicit questions which might betray his scheme; with a view to holding up the conversation, and in order to show himself a well-informed and entertaining man, the person whom he visits will enter into details which he would refuse to give, should it seem that the officer requires them. But be sure to remember what this person said, and endeavour, during the conversation, not only to follow the chain of ideas, but to make them arise from each other in a manner suitable to your purpose. Be particularly careful not to make your appearance in a magisterial attitude, with a pencil in one hand, and a book of memoranda in the other, and avoid studiously, likewise, assuming an air of mystery and importance, and that look of a man who seems to meditate great designs; as without it, you will render yourself suspicious, and people will believe that it may be proper to deceive you; then, either an absolute silence on their side will defeat your views, or they will attempt to mislead you by means of erroneous statements, apparently given in a confidential manner, the consequences of which may prove very fatal to the army.

Should the information which the officer has derived from the archives of the country and the inhabitants be insufficient, the elements of political economy and military administration may supply him with useful means of analogy and induction.

For instance: if he have expressed the nature of the ground in the map drawn from his reconnoitring, he may easily compute, with near approximation, the number of acres, or of any other measures, which both the cultivated and laid-up lands, the meadows, the untilled fields, and the plantations occupy ; the ground itself, or the inhabitants, will afford him the requisite data for dividing the land into some principal classes, according to its nature and fertility; and, by examining the cultivated spots, he will be able to ascertain the manner in which the husbandman alternates his crops ; the mean quantity of grain, forage, and other produce, which is reaped in one acre of land, according to the soil, is known ; and, if an officer possess these elementary notions, he may easily calculate, with sufficient precision, the agricultural product. This product has necessary relations with the buildings which belong to the farms ; and should it be deemed expedient to ascertain the contents of the stacks, granaries, and barns, simple and easy measurements will give it. In all cases, an exercised eye is sufficient for estimating or verifying the resources of a district with rapidity.

The stables, ox-stalls, &c. afford indices, likewise, respecting the number of cattle and beasts of burthen ; other inductions may be drawn from the nature of the country and crops, the meadows, the quantity of manure and number of conveyances which the cultivated grounds require, and from the more or less careful manner in which they are attended to. More positive notions upon the number and nature of animals of all kinds may be easily collected in reconnoitring, and the means of conveyance immediately concluded from them ; the daily product of cattle, the food and materials obtained from it, and the relation in price, quantity, and nutritive quality, that this branch of resources has with vegetable productions, are also data which political economy affords.

With regard to other productions, we know the mean produce of one acre of land, either planted with lofty trees of such or such kind, or forming only a coppice; that of coal and clay-pits is not so easily ascertained, but may be concluded from the quantity of fuel which is heaped up near them, or from the account of the work-people. The daily produce of these people's labour may also be measured, and the same method employed for estimating all other articles of consumption, either dry or liquid, and whatever the size and figure may be of the magazines, sacks, casks, and other capacities, which contain them; nay, the habit of cubing all kinds of solids, and an accurate knowledge of the measures and gaging of the country, will enable an officer to estimate the volume with sufficient accuracy by the eye alone, and to conclude the weight from it.

It is still more easy to take an account, in reconnoitring, of the manufactories of some importance, to make enquiries respecting their product, or to estimate it from the number of hands and working machines which they employ: finally, by means of the general notions which we possess on the mean product of manufactories of the same kind.

Thus it is not more difficult to estimate the resources of a country with regard to the clothing of the troops, their equipment, the supplying of the depôts and fortresses, and to military works in general, than with respect to subsistence.

The nature of the habitations and their number have a multiplicity of relations with the population and chief employment of the inhabitants, which are easily perceived: the general results furnished by the tables of mortality, or collected in reconnoitring, and all those which we have enumerated, will give, without any difficulty, the natural and civil divisions of the population, as well as those relative to industry; the number of hands and professional workmen who may be employed in military works will be known, and particularly the proportion which the consumption of the country bears to its resources; and, consequently, the quantity of these resources which we can properly apply to the wants of the army will be ascertained.

On the other hand, we learn from the elements of military administration what quantity of food, either for the men or horses, what establishments and means of conveyance, what kind and quality of materials, in short, what number of hands are requisite, for the subsistance of an army at large, its clothing, equipment, and fuel, and for military operations and works, according to the strength of the army, the nature of the war, the country where it is carried on, and to other circumstances.—Wherefore an officer who possesses a knowledge of these bases, may easily present general results in his Descriptive Memoir, respecting the means of attending to the wants of the army, and thus enable the commander, as well as government, to determine the quantity of supplies to be added to those which the country can afford, or to regulate after these last the strength, direction, and the operations of the army.

Time, and the limits of this essay, do not allow me to investigate the numerous, but simple and easy elements of the above computations: they should be the subject of a special memoir, comprehending a collection of precepts relative to military statistics. The utility of such collection for officers will undoubtedly not escape the enlightened zeal which directs the labours of the *General Depôt de la Guerre.*

Any officer, who wishes to acquire the necessary qualifications for reconnoitring, should exercise himself in writing and speaking the languages of the countries where he may be employed for that purpose, as such knowledge will be particularly useful to him with respect to Descriptive Memoirs.* If he do not possess it, he will derive great advantages from being sufficiently acquainted with Latin, to converse in this language with the ecclesiastics, monks, and learned men, of the country, and, in some states, with the peasants, as they speak it in a manner more or less perfect. Indeed, this means has proved most beneficial to some officers, but he who employs it should accustom himself to imitate the pronunciation of the inhabitants, so as to be understood by them, and himself comprehend such words as a difference in this respect may first render strange to his ear.

Next to the language of the country, nothing brings an officer so much into favour with the inhabitants as his knowledge of the religion, laws, customs, and manners, there observed, and the respect which he testifies for them: information relative to the government and public administration of the state, and to the civil and political situation of it, utterly removes from him the appearance of being a stranger; he is able to collect, and, therefore, to insert in his Memoir notes relative to the dispositions of the inhabitants; and to point out, in case of agitation among them, the means which should be employed in order to pacify them, or to keep them down. He has it particularly in his power to explain the most simple method of using to advantage, with as few alterations as possible, the measures successfully adopted by the administration of the country, for the maintenance of public tranquillity; as well as those which will cause the contributions in money or otherwise to be equitably divided, and for this reason levied with greater facility: finally, he is enabled to indicate in what manner the product of these contributions, the means of conveyance, and the required workmen for sieges and military works in general, may be forwarded to the army without confusion from all parts of the country.

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* In almost all countries, the inhabitants do not so much consider as strangers people who speak the language of the place, and they are more sociable with them.

The particular abilities which an officer should possess in order to describe a country properly in a memoir, have been pointed out at the beginning of this article: it was supposed that the ramifications of the ground and waters would be thrown together, in separate sheets, at the end of the memoir, and we shall now add that this process is not less adviseable with respect to the population, establishments, and various resources of the country. Some statistical works contain specimens of most of these sheets, which may be easily completed, modified, adapted to reconnoitrings, and subjoined to special instructions in military statistics.

In general it is proper, in a Descriptive Memoir, that all kinds of details should be thrown at the end, in separate sheets, as aforesaid, so that the body of the memoir may only contain a general view of the country, the comprehensive descriptions, principal observations, and most striking remarks; in a word, those most important objects of information which require illustrations, suppose some discussions, and suggest highly useful observations: in this manner, the memoir will have that kind of precision which is so requisite in writings intended for the perusal of men entrusted with the direction of great concerns, that perspicuity which only requires a glance over it, and, in short, that arrangement, pleasing to the reader, which relieves his attention and diminishes his fatigue. Every officer may show his particular abilities in this respect; Buffon is eloquent, and Fontenelle ingenious, even in treating of subjects which least favour a display of these qualifications. Indeed, it is not given to all men to possess them, but every one may employ a clear, simple, and concise, style, which, particularly in writings of this kind, is the most approved, as being the most useful; nay, any other style may give rise to dangerous consequences, and therefore the author of a Descriptive Memoir should not use forced expressions.—Besides, emphasis borders upon ill-suited eloquence, refinement upon affectation, and pretensions most commonly lead to ridicule.

ARTICLE XIV.

On Military Memoirs.

MILITARY Memoirs differ from those which are only descriptive, as the writer does not confine himself in the former to describing in a general way the nature of the country, its resources, and the obstacles which it opposes to the operations of armies, but makes applications of these data as he collects them. He supposes, for instance, that armies are acting upon the ground which he passes over, and that their respective strength, some misfortunes, or their successes, place them in such or such a situation; and upon each hypothesis, he considers, analyses, and discusses the measures which they ought to take, in order to recover their disasters, or profit by their victories. These suppositions are frequently less vague, and have for their object to investigate the means of attaining a fixed purpose. Such are the circumstances in which an officer is to indicate the roads which the different columns may follow; to choose a camp; to observe the position and movements of the enemy; to reconnoitre the defensive or other works, the new roads, the intrenchments, blockades, surprises, and sieges, which the operations of an army may require, and to lay the plan of their execution; to propose means for defending a great extent of country, while the armies are acting offensively at remote points: in short, to determine the actual relations of the armies, ground, fortresses, and posts, in defensive or offensive operations, and either upon our frontiers, or in the country of the enemy.

The rules and processes applicable to Military Memoirs, as well as the means of analogy, induction, and approximation, do not differ from those which are applied to Descriptive Memoirs in reconnoitring and surveying the country, and in making a plan or a written description of it; but the former Memoirs demand a more extensive and precise knowledge of war than the latter, and, in many circumstances, of military works. The enumeration made in the Articles I. and II. of this essay, of the subjects of information which war requires, will remind the reader of the principal considerations which the various military operations oblige us to embrace, wherefore I will refer him to those articles; and, with regard to such investigations as they did not admit of, he may consult the most esteemed military publications. I only propose, in this place, to offer some remarks upon the means of execution with which an officer ought to render himself familiar, in order to digest and form a Military Memoir with the promptitude and degree of precision requisite in war.

The first of these means is the great practice which he ought to have in estimating at sight the space which an army, or a detachment of a given strength, their equipages, and a park of artillery, require in camps, positions, and quarters; and when time permits, in verifying this space by the paces of his horse: an officer should also be acquainted with the different methods of arranging the troops, waggons, guns, &c. and know the limits within which the surfaces where they are placed may be extended or contracted, according to the ground and the greater or smaller distance of the enemy. In fact, if the reader only apply these assertions to the most frequent occurrence, he will perceive that an officer, who is to reconnoitre the spot for a camp, has no other means of ascertaining that it will fulfil the first requisite condition; namely, that it will be suitable to the strength of the army, and such as to be wholly occupied, as well as supported and defended at all points, without the troops being too much weakened.

It is not less necessary that an officer should exercise himself in estimating the space which, in marches, an army of a given strength, a certain body of troops, their artillery and equipages, shall occupy; as well as the distance which they can pass over, and the possible arrangements in their respect, according to the roads, the particulars of these last, and to the nature of the proposed operations. Estimations of this kind are incessantly requisite, either in reconnoitrings relative to the directions which columns and convoys are to follow, and to the places of halting and sojourning, or in indicating the obstacles opposed by the required dispositions and measures for the passage or the defence of *cols*, defiles, bridges, streams, and rivers, and for attacking or defending camps, positions, quarters, columns in their march, and convoys; similar estimations are also made in examining

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In recommending this method, we undoubtedly except the case in which an officer knows the purpose of the reconnoitring, is in the confidence of his general, and receives directions from him to prepare or propose a plan for the execution of such or such determined operation; but then he evidently has no suppositions to make; he is no longer to discover the views of the general, since he is acquainted with them, and his only duty is to investigate the most proper means of carrying them into effect.

The above officer has frequently occasion to mark the position and movements of the troops, upon the map of the reconnoitring, and to subjoin in the same manner, but from a larger scale, the defensive and other works: at all events, this kind of drawing will not appear difficult to him if he be acquainted with plan-drawing, and possesses also the necessary information to project the movements and works which he is to represent.

Finally, it often happens that circumstances do not allow an officer to write down his observations, but only to give a verbal account of them to his general, and to make what is called a *Military Report*. This takes place whenever the object of the reconnoitring is a pressing operation, in the execution of which great promptitude is requisite. It is important in this case that the officer should possess, besides the other qualifications which the peculiar nature of his service requires, a sure and rapid *coup d'œil*, an imagination ready to seize all particulars, much coolness, a strong memory, and the rare faculty of expressing clearly, in a few words, every thing essential to be remarked in the series of objects and events which have struck him.

ARTICLE XV. AND THE LAST.

Conclusion.

THE various kinds of information which war requires have been briefly enumerated in the leading articles of this essay; they are the intended object of military reconnoitrings, wherefore we have, first, treated of them.

The different means of observation have then been investigated; such investigation was the principal purpose of this work. The instruments, processes, rules, and analogies, which may be successfully used either for abridging the operations or multiplying the results, have been particularly pointed out, and the description of all these resources will enable officers to know the proper limits of their undertakings, according to the time which they can command, the country where they operate, and consistently with other given data: it will assist, perhaps, in preventing two opposite faults; namely, that of doing less than can be done, and that of attempting impossibilities.

We shall observe, however, that the methods which have been explained are not all applicable to every place, in every case, or suitable to all military men; wherefore, each officer should endeavour to select and use such of them as are adapted to his personal means, the operation with which he is entrusted, and to the degree of precision that it requires.

Indeed, the information which the use of these methods supposes is very elementary: the instruments and processes relative to the rapid formation of the outlines of triangles, and to comprehensive levellings, are the only ones of which the application requires that kind of knowledge which the peculiar duty of an engineer renders necessary to him, and the general notions contained in this essay, upon those two operations, present no difficulty in being understood; while they will prove useful to officers engaged either in taking the details of a survey, or in levellings of no great extent. These operations, the methods of taking heights and distances which are recommended, and those of performing surveys in which chains, rods, or only pacing, are used for measuring, merely require a knowledge of the first rudiments of geometry, and are as little complicated as the elementary problems of tactics; on the other hand, any man of common information may easily comprehend, with a little attention, most of the experiments and observations relative to optics, perspective, and physical geography, and find in them facts which he has previously witnessed: he also may verify them in maps, in his travels, and in considering the objects about him, by using for this purpose observations suitable to himself. Here it is not required to explain phenomena, but merely to observe them; and, instead of theoretical studies, only a few simple, positive, and practical notions are to be acquired: nor is it requisite for reconnoitring, that an officer should possess a deep knowledge of the sciences connected with this branch of service, as it is sufficient for him to be acquainted with the results, and to apply them to war.—There is not any thing in these applications, of which war in its turn does not give an example: for, all branches of knowledge are connected with each other, although they may relate to different subjects; each derives assistance from the others, and if we consider the military art in all its ramifications, we shall perceive that it has relations with every other art.

The easiest methods are also the most usual in reconnoitring, as the application of those which present some difficulties is less frequently requisite: it is the same thing for all branches of practical knowledge; wherefore improvement in their respect does not consist in contriving all kinds of processes, but only such as may be conveniently employed, and are simple and rapid. This assertion will account for the particular attention bestowed in this essay upon the investigation of the means which every military man may use.

In this multiplicity of means, all are not equally good, although all may be useful; consequently, an officer should know the whole of them, not in order to employ them indiscriminately, but for the purpose either of selecting them when he may take his choice, or of being able to use such of them as he has at hand, were he destitute of other resources. Indeed, some of those means are very imperfect, but they sometimes are the only ones to which recourse can be had; and if, on the one hand, they only give rough approximations, it may happen, on the other, that the circumstances in which they are employed, do not require greater precision; thus the variety in the degree of approximation which may be requisite, compensates for the imperfection of some means, and justifies the multiplicity of those which we have pointed out in this work.

In general we have been guided in our researches by the same principle that ought to guide an officer in reconnoitring; namely the necessity of having regard to time, which fixes the limits of possibility, decides every thing in war as well as in politics, and has no less influence on events, determinations, and passions, than it has upon matter itself.

THE END.

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